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All communications should be addressed to the Editor.

No. 137. MAY, 1922. VOL. XXVI.

Notices of the Royal Aëronautical Society.

Council.

As a result of the ballot of members declared at the Annual General Meeting the full Council for the year 1922-23 is as follows :—

Lieut.-Colonel M. O'Gorman, C.B. (Chairman); Brig.-Gen. R. K. Bagnall Wild, C.M.G., C.B.E.; Prof. L. Bairstow, C.B.E., F.R.S.; Mr. Griffith Brewer, Wing Commander T. R. Cave-Browne-Cave, C.B.E.; Sir Mackenzie Chalmers, K.C.B., C.S.I.; Mr. H. P. Folland, Sir Robert Hadfield, Bart., F.R.S.; Capt. G. de Havilland, A.F.C.; Squadron Leader R. M. Hill, M.C., A.F.C.; Prof. C. F. Jenkin, C.B.E.; Prof. B. Melvill Jones, A.F.C.; Lieut.-Col. J. T. C. Moore-Brabazon, M.C., M.P.; Mr. J. D. North, Lieut.-Col. A. Ogilvie, C.B.E.; Dr. A. J. Sutton Pippard, Major-Gen. Sir R. M. Ruck, K.B.E., C.B., C.M.G.; Col. the Master of Sempill, A.F.C.; Major R. V. Southwell, Lieut.-Col. H. T. Tizard, A.F.C.; Major H. E. Wimperis, O.B.E.; *Hon. Treasurer*, Mr. A. E. Turner.

Lectures.

The following programme of lectures has been arranged for next session :—

Oct. 5. Prof. L. Bairstow, Fellow. "The Work of S. P. Langley."
,, 19. Mr. J. D. North, Fellow. "The Metal Construction of Aeroplanes."
Nov. 2. Major A. R. Low, Fellow. "A Review of Airscrew and Helicopter Theory, with Aeroplane Analogies."
,, 16. Mr. R. McKinnon Wood, Fellow. "The Co-relation of Model and Full-Scale Work."
Dec. 7. Prof. C. F. Jenkin. "Fatigue in Metals."
Jan. 4. (To be announced later.)
,, 11. Juvenile Lecture. (Title to be announced later.)
,, 18. (To be announced later.)
Feb. 1. Mr. G. S. Baker. "Ten Years' Testing of Model Seaplanes."
,, 15. Wing Commander Cave-Browne-Cave. "The Practical Aspects of the Seaplane."
Mar. 1. Major F. M. Green. "Helicopters."
,, 15. (To be announced later.)

Programme for the Students' Section.

Friday, April 28th.—Library of Royal Aeronautical Society, 6.45 p.m. Student's paper (postponed from March 23rd), "Some Notes on Commercial Aircraft," by Stanley H. Evans. Mr. H. P. Folland, Fellow, in the chair.

Saturday, May 6th.—Visit to the de Havilland Aircraft Works, Edgware. Meet at Works 10.0 a.m. Bus leaves Kilburn Park Station (Bakerloo Tube) at 9.30 a.m.

Wednesday, May 31st.—Visit to the Royal Aircraft Establishment, South Farnborough. Meet at 8.40 a.m. for special tickets at Booking Office, Waterloo Station (L. & S.W.R.) for 9.0 a.m. train.

Saturday, June 3rd.—Visit to the National Physical Laboratory, Teddington. Meet at 9.15 a.m. for special tickets at the Booking Office, Waterloo Station (L. & S.W.R.).

Students are requested to give in their names *immediately* for the visits they wish to attend in order to obtain cheap travel facilities. The Hon. Secretary will meet students at places and times mentioned for issue of these tickets.

Students are also asked to send in early this month (May) promises of papers for the Students' Section for next Session, 1922-1923.

Associate Fellowship Examination.

The Council have decided, as a result of representation which has been made to them, to hold the examination for Associate Fellowship in September instead of in April this year, as it has been found that this would be more convenient for the majority of students who desire to sit for the examination, owing to their studies having been delayed by the war. Intending applicants should forward their names to the Secretary not later than July 31st.

Library.

The Society's lantern is being repaired so as to make it available for students' discussion meetings and other meetings in the library. The Finance Committee have also authorised expenditure on extra bookcases, which are urgently needed. Will any member, therefore, who hears of a good bookcase, preferably oak, with glazed doors, kindly communicate with the Secretary?

The following books have been received and placed in the library:—"Grundlagen der Flügtechnik," Dr.-Ing. H. G. Bader. "Notes and Examples on the Theory of Heat and Heat Engines," John Case. "La Photographie Aerienne," A. H. Carlier. "Cours Pratique d'Aviation," Capt. Gambier and Lieut. de V. Amet. "Research in Industry," A. P. M. Fleming and J. G. Pearce. "Airplane Engines," L. S. Marks. "Gas, Petrol and Oil Engines," D. Clerk. "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Lüftfahrt," Dr.-Ing. L. Prandtl. "Ergebnisse der Aerodynamischen Versuchsanstalt zu Gottingen," Dr.-Ing. L. Prandtl. "Verhandlungen der Versammlung von Vertretern der Flugwissenschaft," Dr.-Ing. L. Prandtl. "Catalogue of the Collections in the Science Museum, South Kensington (Aeronautics)," Board of Education.

W. Lockwood Marsh, *Secretary.*

ANNUAL GENERAL MEETING.

The Fifty-Seventh Annual General Meeting of the Society was held in the Society's Offices, 7, Albemarle Street, London, at 5.0 p.m., on Tuesday, March 28th, 1922. The Chairman, Lieutenant-Colonel M. O'Gorman, C.B., D.Sc., presided, and the following were present :—

Council.—Sir Mackenzie Chalmers, Lieutenant-Colonel A. Ogilvie, Dr. A. J. Sutton Pippard, Major R. V. Southwell, Major H. E. Wimperis.

Members.—P. Y. Alexander, R. L. Balston, Griffith Brewer, Miss L. Chitty, H. Glaser, Dr. Hilda Hudson, W. O. Manning, C. F. Dendy Marshall, H. A. Mettam, P. C. Thornton, Dr. R. Mullineux Walmsley, and F. P. Walsh.

Miss L. Chitty, Mr. R. L. Balston and Mr. W. O. Manning were appointed scrutineers of the ballot for the election of Council.

The Chairman, in presenting the Council's report and balance sheet, said that though there had been a slight drop in the membership, he did not think this was surprising in view of the bad times being experienced in aviation. He felt that members could do a great deal to induce more members to join the Society. Besides the technical grades of the Society, there were the subscribing grades, to which anyone interested in the subject and sufficiently well-wishing to the cause was eligible. The fact that the membership had not dropped more was due to the activity of their energetic staff.

He called attention to the benefits which the Society now offers in the way of prizes. There is the Silver Medal of the Society, which is awarded to the best Paper published in the JOURNAL in the year; and for Students there is the Society's Bronze Medal, for the best Paper by a Student published in the JOURNAL during the year. Besides these there is the Pilcher Memorial Prize for Students, to be awarded to the best Paper in each year inaugurating discussion at one of the Students' Meetings. The Students' Section had had several meetings for discussion, and an interesting programme of visits had been arranged for the summer.

Another point which he would like to mention was the technical lectures before the Society. He thought that many members miss a great deal by not attending these meetings, and he felt sure that they would come if they realised how very good they are. Reading the papers in the JOURNAL afterwards was quite a different thing from actually hearing them read and discussed.

In conclusion he read the Honorary Treasurer's statement on the financial position, which showed that members could congratulate themselves on a considerable improvement.

The adoption of the Report was proposed by Colonel Ogilvie, seconded by Mr. Dendy Marshall, and carried unanimously.

The scrutineers then presented the result of the ballot, and the following members were declared elected to serve on the Council for the two years ending March, 1924 :—

Brigadier-General R. K. Bagnall Wild, C.M.G., C.B.E., Mr. Griffith Brewer, Mr. H. P. Folland, Squadron Leader R. M. Hill, M.C., A.F.C., Professor C. F. Jenkin, C.B.E., Professor B. Melvill Jones, A.F.C., Mr. J D. North, Lieutenant-Colonel A. Ogilvie, C.B.E., Dr. A. J. Sutton Pippard, and Major H. E. Wimperis, O.B.E.

The meeting closed with a vote of thanks to the scrutineers and the Chairman, proposed by Sir Mackenzie Chalmers.

PERFORMANCE TESTING OF AIRCRAFT.

Lecture delivered before the Cambridge University Aeronautical Society on February 8th, 1922, by Squadron Leader T. M. Barlow.

Introduction.

One of the factors contributing to the rapid development of aviation during the last few years has been the testing of aircraft conducted on systematic and scientific lines. Even more so, perhaps, future development is dependent on this branch of aeronautics especially when one considers we are still in the early stages of experimental research. Theories are excellent in their own sphere, but when applied to aviation must be treated with more respect than usual, as failure to materialise in practice is a matter of personal risk apart from the financial aspect of the case. Designers and constructors cannot make real progress unless they are provided with accurate and reliable data from performance trials of aircraft. Model testing, intricate mathematical calculations and assumptions do much towards predetermination of results, but after all the main thing that matters is practice, whether concerned with military or civil aircraft. In fact, the performance testing of aircraft forms that connecting link in the union of theory and practice which is absolutely essential for the efficient success (efficient in all senses of the word) of any machine or engineering structure.

I propose in this paper to give an outline of the performance testing of aeroplanes, as carried out in this country, with special reference to the routine work at the R.A.F. Aeroplane Experimental Establishment, Martlesham Heath. At this point I should like to place on record the fact that the general scheme of aircraft testing, as given in Col. Tizard's paper read before the Royal Aeronautical Society in 1917, has formed the base on which has been constructed and developed the present methods.

Standard Atmosphere.

Comparison of aircraft performances obtained from data of test flights carried out in different places and under various atmospheric conditions cannot be made unless such results are corrected to the performances which the aircraft would have if flown under identical atmospheric conditions. It is essential, therefore, that some form of standard atmosphere should be adopted. In England until quite recently, a mean of atmospheric records observed by the Meteorological Office during several years was taken as standard. This agreed remarkably well with the climate in East Suffolk (Martlesham Heath). France adopted Radaus law for variation of temperature and pressure with height. The United States, I believe, for a time worked to both. It was with a view to co-ordinating all available information on the subject that the Technical Section of the French Air Service, after considerable research into meteorological records of England and Europe, was able to arrive at simple empirical laws for a standard atmosphere. Present information states it is extremely probable that this standard will become international. At present it is used by both the English and French Technical Services.

The standard atmosphere is based on a straight line law for variation of temperature from given initial ground level conditions to a height of 11,000 metres. Above this height is considered isothermal.

The following are the main empirical equations and conditions of the standard atmosphere.

(1) Ground level. Zero height.
Height in metres. H. = 0.
Temperature in degrees Centigrade. $\theta = 15°$.
Pressure = $P_0 = 10.33$ kgs. per sq. metre.
Corresponding to 760 mm. of mercury.
This gives a standard density of 1.225 kgms. per cub. metre.

(2) From 0 — 11,000 metres.
Law of Temperatures.

$$\theta_H = 15 - 0.0065H.$$

Law of Pressures.

$$P_H/P_0 = \{ (288 - 0.0065H)/288 \}^{5.255}$$

Law of Densities.

$$\rho_H/\rho_0 = \{ (288 - 0.0065H)/288 \}^{4.255}$$

(3) Above 11,000 metres (Isothermal).
Law of Temperatures.

$$\theta_H = 56.5°.$$

Law of Pressures.

$$\log P_H/P_H = (H - 11000)/14600.$$

Law of Densities.

$$P_H/P_0 = \rho_H/\rho_0.$$

The agreement between this temperature gradient law and the average experienced in East Suffolk during twelve months is shown in Fig. 1. This has been prepared from the temperature records of all test flights carried out during the year up to 17,000ft. The chart also shows the limits of winter and summer observations.

The empirical laws give us a standard height and a variation of density, and charts showing this relationship, preferably expressed as percentage of standard density (ground level), form the means of reference from correcting the actual flight results to the standardised form for comparison purposes.

A further assumption, and a most important one, is that engine torque varies in proportion to the density of the surrounding air. This is not strictly correct. Tests carried out at the Royal Aircraft Establishment, Farnborough, U.S.A. and France on engines run in sealed chambers under artificial height conditions have shown that variation in proportion to pressure is a true assumption. However, actual flight trials under winter and summer variations of density do not give appreciable differences in performance when reduced to standard atmospheric conditions on the density assumption. Apart from this, the method is simpler and quicker; also there is no need for engine power curves to be taken during the trials. On consideration having been given to these points and bearing in mind that all results are comparative, both French and English testing aerodromes have adopted the assumption.

The reduction of results works out in a very straightforward and easy way. Before going on to describe the general proceedings to be adopted in testing I propose to outline the method.

To obtain the density of the surrounding air in which an aeroplane is flying one requires readings of pressure and temperature. The former are obtained by using either the ordinary form of altimeter with a fixed zero or recording barograph, the readings being pressures. The temperature of the air is read from special thermometers fixed in a suitable position. From these two readings the density can be calculated or preferably read off from suitable charts and is

best expressed as a percentage of the standard density. From the relationship between standard height and density it is thus possible to obtain the standard height of the aeroplane.

Both speed and climbing qualities of the aeroplane are referred to this standard height.

Dealing with climb first, by means of an altimeter and stopwatch or recording barograph aneroid rate of climb can be obtained at any height and therefore at any standard height by taking tangents to the aneroid height time curve. But

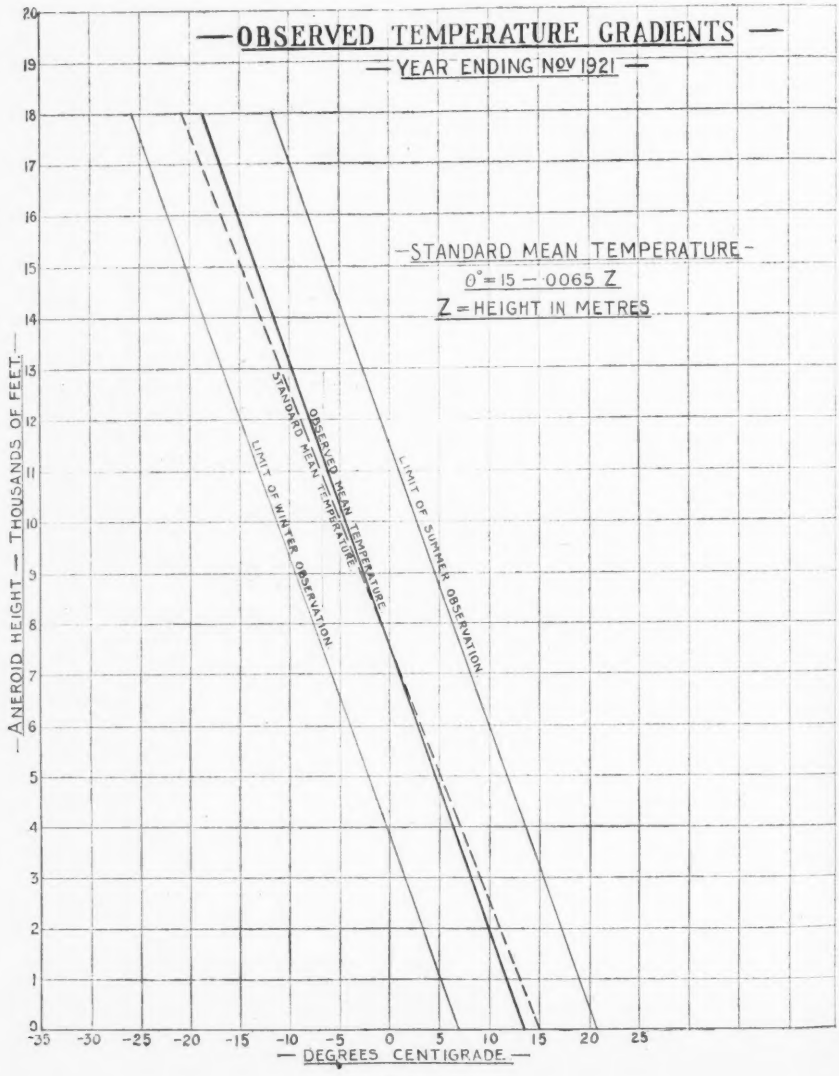
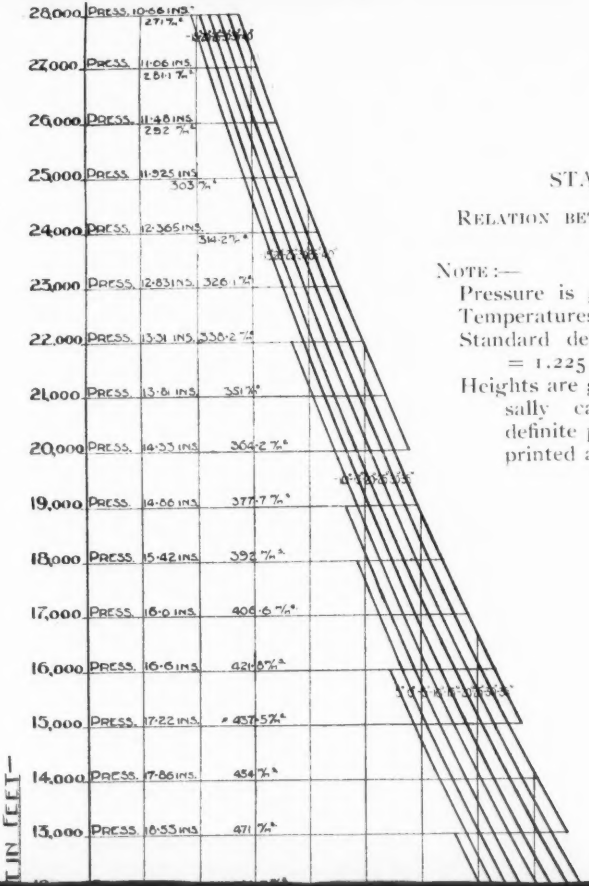


FIG. 1.



STANDARD ATMOSPHERE.

Relation between Pressure, Temperature and Percentage Density.

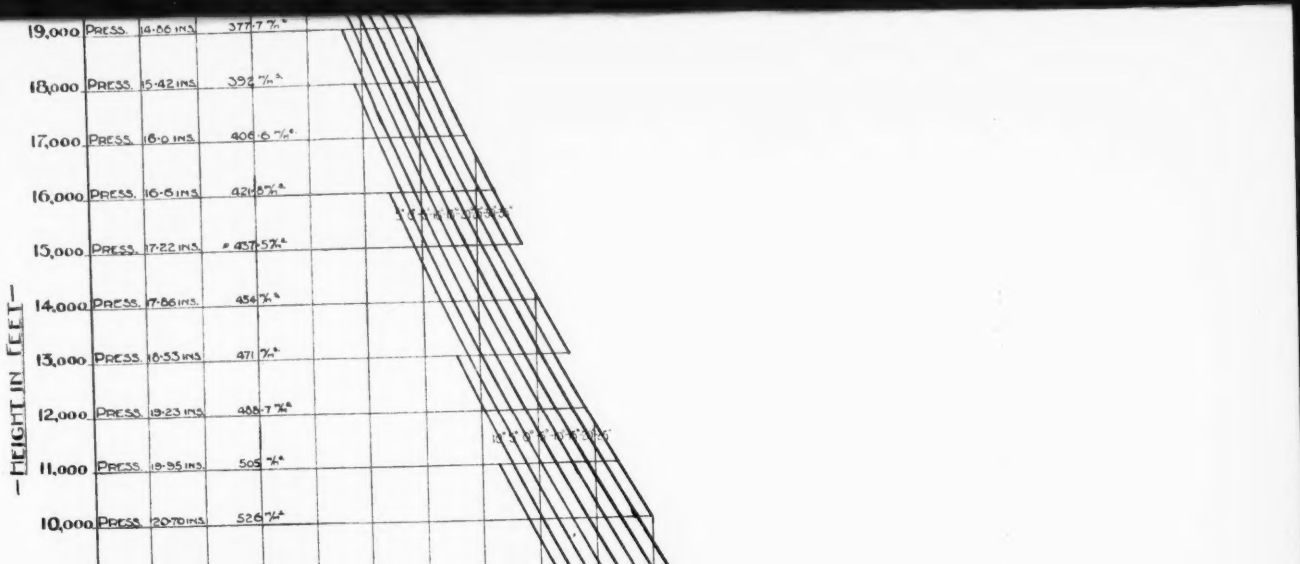
Note:—

Pressure is given in inches and $^{m}/_{m^{s}}$ of mercury.

Temperatures are given in degrees Centigrade.

Standard density (100% at 700 $^{m}/_{m^{s}}$ and 15°C.) = 1.225 kgms. per cu. metre.

Heights are given as indicated by an aneroid universally calibrated and corresponding to the definite pressures in inches and $^{m}/_{m^{s}}$ of mercury printed alongside.


19,000 PRESS. 14·86 INS. 377·7 %
18,000 PRESS. 15·42 INS. 392 %
17,000 PRESS. 16·0 INS. 406·6 %
16,000 PRESS. 16·6 INS. 421·8 %
15,000 PRESS. 17·22 INS. 437·5 %
14,000 PRESS. 17·86 INS. 454 %
13,000 PRESS. 18·53 INS. 471 %
12,000 PRESS. 19·23 INS. 488·7 %
11,000 PRESS. 19·95 INS. 505 %
10,000 PRESS. 20·70 INS. 526 %
— HEIGHT IN FEET —

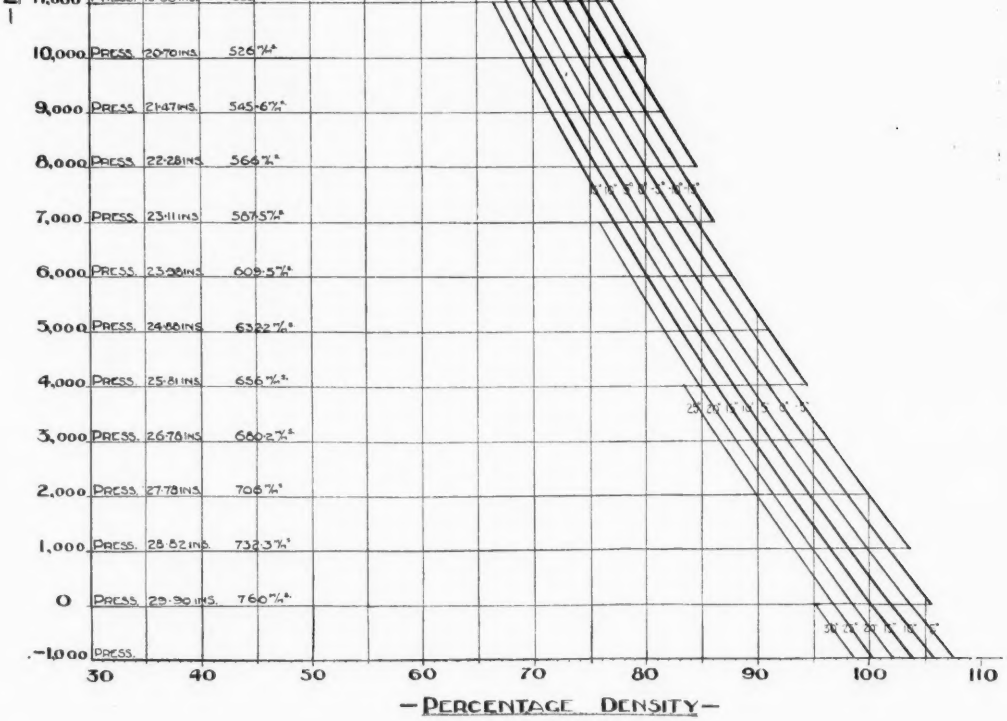

10,000 PRESS. 20·70 INS. 526 %
9,000 PRESS. 21·47 INS. 545·6 %
8,000 PRESS. 22·28 INS. 566 %
7,000 PRESS. 23·11 INS. 587·5 %
6,000 PRESS. 23·98 INS. 609·5 %
5,000 PRESS. 24·88 INS. 632·2 %
4,000 PRESS. 25·81 INS. 656 %
3,000 PRESS. 26·78 INS. 680·2 %
2,000 PRESS. 27·78 INS. 706 %
1,000 PRESS. 28·82 INS. 732·3 %
0 PRESS. 29·90 INS. 760 %
-1,000 PRESS.
30
40
50
60
70
80
90
100
110
— PERCENTAGE DENSITY —

FIG. 2.

the aneroid or barograph can only record true change of height at its international calibration standard 10° Centigrade and must be corrected in the ratio of absolute temperatures before being plotted as a rate of time curve against standard height, *i.e.*, the factor is :—

$$C = (273 + t°)/283 \text{ where } t = \text{temperature in degrees Cent.}$$

Having thus obtained time rate of climb at any standard height by reversing the procedure an actual standard height time curve follows.

True speeds at any standard height are calculated from the air speed readings after due allowance has been made for pitot and instrument errors in the ordinary way by dividing by density.

The charts referred to are shown in Figs. 2, 3 and 4.

General Procedure for Performance Testing of an Aeroplane.

Although an aeroplane will be taken as an example, it should be understood that the methods used apply equally well to seaplanes, flying boats and amphibians with quite minor modifications. The order of operations is :—

(1) General particulars of the aeroplane. Weighing and determination of centre of gravity.
(2) Preliminary handling flight tests and climbing speed trials.
(3) Speed course.
(4) Climbing and speeds at height tests.
(5) Special tests, consumption trials, "getting off" and "landing" trials.

(1) General Particulars of the Aeroplane.

In considering a performance report on any particular aeroplane one must be absolutely sure of the main features of the design. I mean that wing areas, control surfaces, all rigging angles, thrust line position, propeller pitch and diameter, etc., must be taken by actual measurement and observations. It is not sufficient to trust to drawings as often, especially in experimental work, quite important modifications are put through and by an oversight not recorded on the drawings. This preliminary ground work, therefore, although simple, must be done with extreme accuracy and cross checked where possible. Weighing, perhaps, is all important, and is the clue to the many differences in performances obtained by pilots at different aerodromes. It should be done by schedule, *i.e.*, from the weight bare a full detailed list is necessary of all additions to bring the aircraft up to its specified military or civil load. This sounds quite easy but is often confusing, as minor things like gun mountings, part of useless gear, small amounts of petrol in gravity tank overlooked make a difference in the final balance sheet. The weighings necessary are :—

(*a*) Weight light, *i.e.*, no petrol or oil, but water in cooling system if not air-cooled engines, no live load and no military load as, for example, bomb racks, wireless, etc.

(*b*) Weight full of fuel; also petrol and oil tanks filled up, quantity being measured. By taking the specific gravity a check on the first weight is obtained.

(*c*) Weight with specified load. This, in the case of service aircraft, includes all crew, military load, and in the case of civil aircraft crew and passengers, luggage, etc.

The actual position of the centre of gravity should be taken during weighings light with specified load, thus again giving a check.

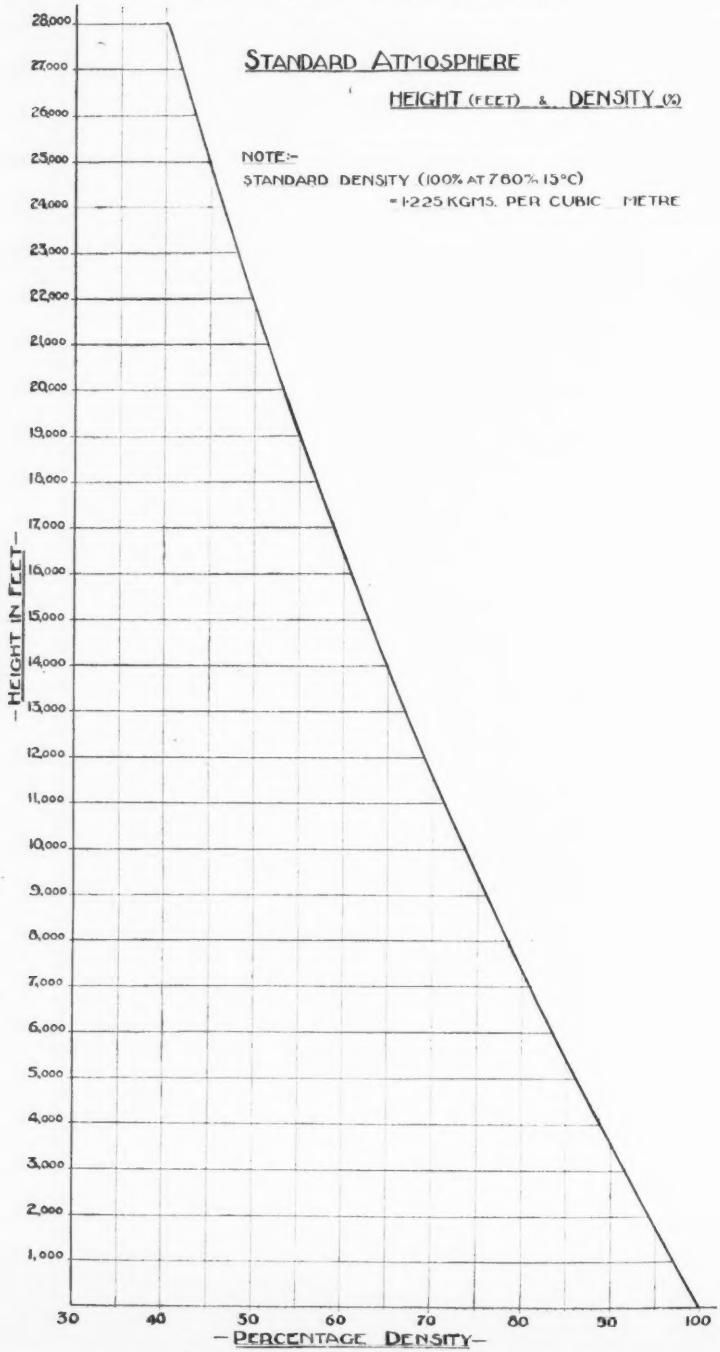

STANDARD ATMOSPHERE
HEIGHT (FEET) & DENSITY (%)
NOTE:-
STANDARD DENSITY (100% AT 760% 15°C)
= 1·225 KGMS. PER CUBIC METRE
— HEIGHT IN FEET —
28,000
27,000
26,000
25,000
24,000
23,000
22,000
21,000
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
30
40
50
60
70
80
90
100
— PERCENTAGE DENSITY —
TEMPERATURE — DEGREES CENTIGRADE

FIG. 3.

I should like to emphasise the importance to know the actual C.G., as with large aircraft it is extremely difficult to predetermine its position by calculation under full load conditions. If, therefore, the C.G. turns out to be somewhat extraordinary for the wing section used, immediate steps can be taken for readjustment of weights before full load flight tests are made. Even the best designers' C.G.'s do go astray sometimes simply because they are confirmed optimists.

The principle of determination is the usual one of taking the wheel and skid loads in two positions, *i.e.*, with tail down and raised. The actual measurements taken in practice vary, but Fig. 5 gives an accurate method of arriving at the position using the standard reference measurements which are the distance along the chord from the leading edge of the lower plane and the vertical distance above or below this chord. With ordinary trigonometrical equations the above are all that are required to give OX and OY and thus position the C.G.

In the case of an aeroplane with a variable chord wing section some definite chord must be fixed, *i.e.*, by quoting chord at a certain distance out from the centre.

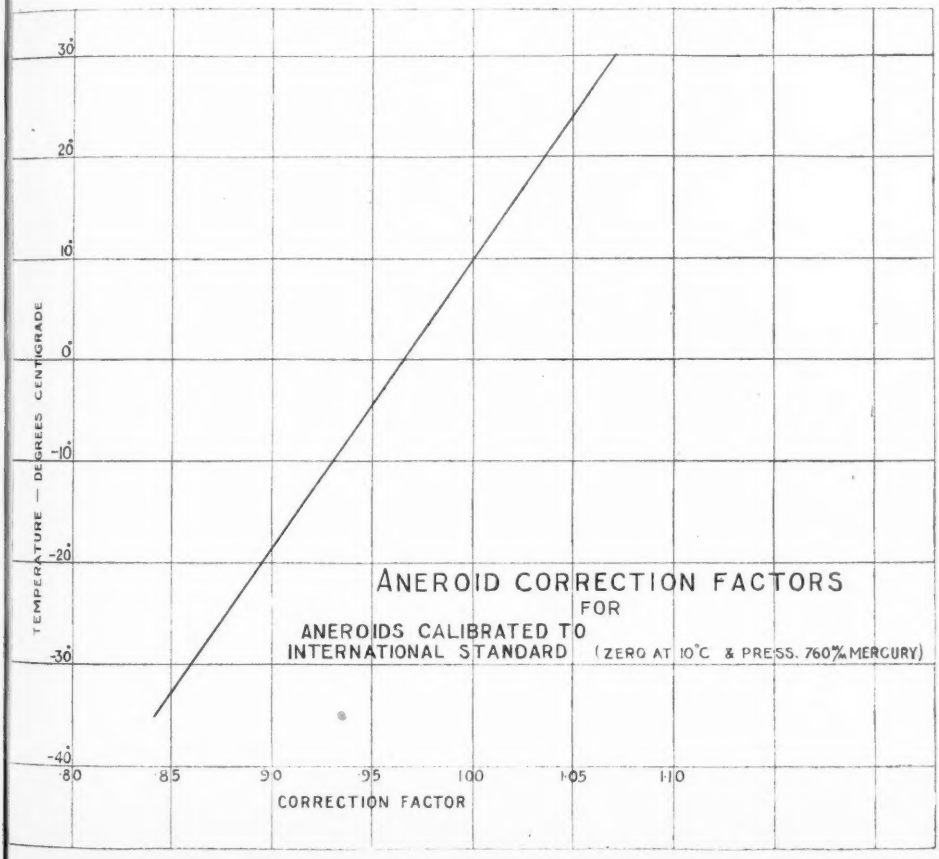


FIG. 4.

Apart from the ordinary weighing precautions there are two points to watch. First, the aeroplane must be out of all wind; secondly, the skid must be locked in one position so that there is not side load on the top of the tail skid weighing machine which might cause binding. If there is a big difference in tail load in the two positions it is possible for the shock-absorbing gear on the undercarriage to give a little and vary the distance of wheel centre relative to the chord. This may be prevented according to design of gear used.

(2) Preliminary Handling Tests and Climbing Speed Trials.

These flights are essential so that the test pilots can familiarise themselves with engine and aeroplane controls and any tricks for "landing" or "taking off." A test pilot must, during actual performance flights, be able to give his whole

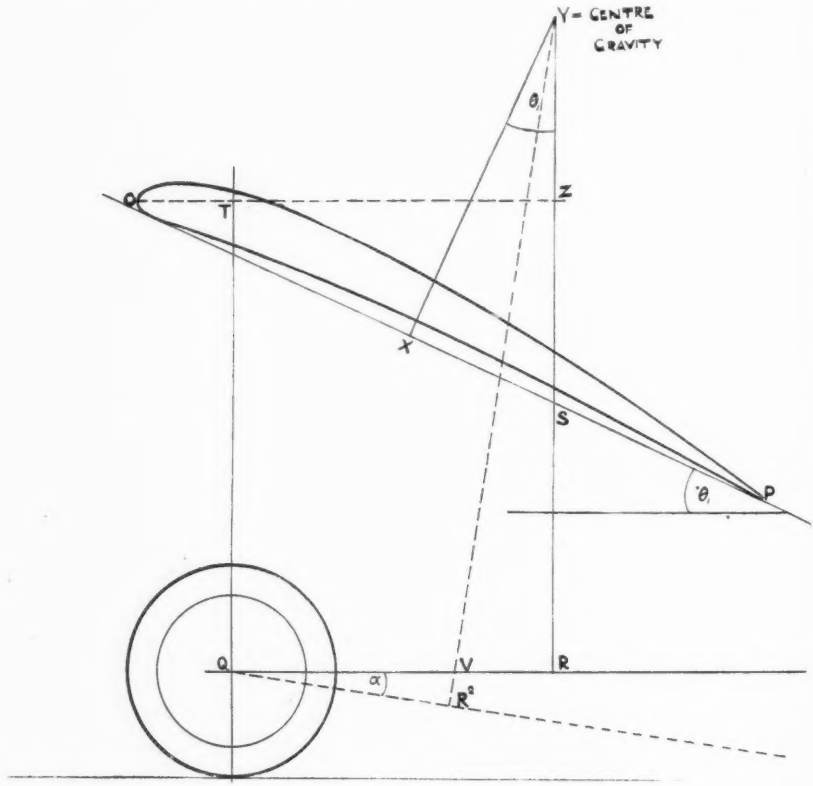


FIG. 5.

W = Total weight.
w_1 = Weight on tail in 1st position.
w_2 = ,, ,, 2nd ,, tail of aeroplane being turned through α.
L_1 and L_2 = Horizontal distances between tail skid and wheel centres for the two positions.
θ_1 and θ_2 = The angles of incidence for the two positions $\alpha = \theta_1 - \theta_2$.
H = Height of leading edge of reference chord above wheel centre = QT.
h = Horizontal distance of leading edge from the wheel centre = OT.

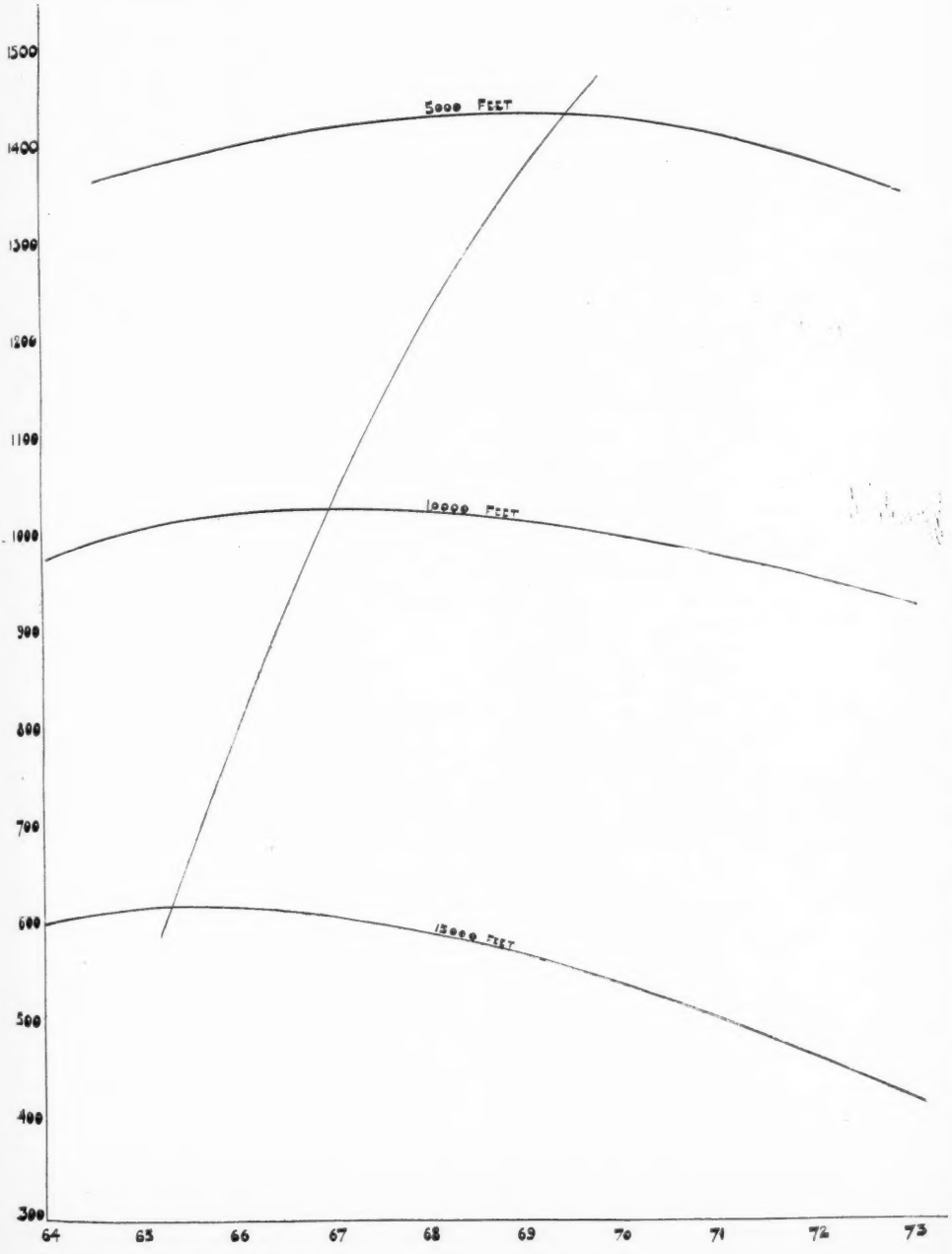


FIG. 6.—*Tests for Climbing Speeds.*

attention to the particular test being carried out, the actual flying and control being as natural as possible.

The best practice is to fly the aeroplane lightly loaded before full load is tried. During this period any minor modifications can be made which are often necessary. Full load climbing speed tests form the first real flight test. The aeroplane is climbed at different A.S.I. readings for 1,000ft. at various heights against stopwatch. A series of curves are then plotted from which the best range of climbing A.S.I. speeds follow (see Fig. 6).

(3) Speed Course.

The air-speed indicator of an aeroplane, apart from density correction and actual instrument errors, very rarely gives the true speed on account of pitot position errors. The pitot head is very sensitive to any position other than straight to wind and also to any slightly disturbed air flow in the neighbourhood. To correct for all possible errors, actually timing the aircraft over definite distances has proved to be the most efficient method. In the case of scouts and small aircraft this is best done over a ground course. For heavier aircraft the camera obscura system undoubtedly gives the more correct results, as the pilot is able to concentrate more on the test than he would do when flying a large aeroplane at level speeds about 20ft. to 30ft. off the ground—a risky procedure.

For the ground speed course at Martlesham Heath a tape machine apparatus is used. This consists of an ordinary motor-driven tape machine fitted with two ink pens which as the tape passes through gives two parallel straight lines. To obtain a time scale, one pen is clicked at right angles to the line by means of a solenoid worked through a seconds pendulum and electric contacts. The second pen can be clicked in a similar way by tapping keys at each end of the measured course, which are electrically connected. Two operators through suitable sights can thus obtain a permanent record of the time over the course. Fig. 7 shows the electrical connections of the apparatus together with an actual tape record. The record is part of the speed test of the Napier "Lion" Mars I. of the Gloucester Aviation Co. when breaking the speed record.

To obtain sufficient points for a correction curve the aeroplane is flown at five different air speeds (highest to lowest) up and down the course. Strength of wind and direction of wind are specially noted for each run and allowed for. If V_1 is the average of the speeds up and down the course and the wind speed is W at an angle ϕ to the course, it follows that :—

$$\text{V true speed} = \{ V_1^2 + (W \sin \phi)^2 \}^{\frac{1}{2}}$$

i.e., air speed is equal to the square root of the sum of the squares of the mean speed and the component of the wind across the course. The effect of an error in wind measurement varies.

(*a*) Any moderate error in the measurement *of a wind across the course* is negligible. Thus a wind of 3 to 5 m.p.h. across the course only affects the results by $\frac{1}{3}$ per cent. if the aeroplane is moving at 60 m.p.h. and by $\frac{1}{6}$ per cent. if it moves at 120 m.p.h.

Since trials are not done in a strong wind, the whole correction for wind across the course is always very small and an error of 30 per cent. in its measurement is permissible.

(*b*) With a steady wind up and down the course, errors of measurement are also negligible since their efforts are completely eliminated by taking the mean of the speeds up and down the course.

(*c*) With a *variable wind* up and down the course, large errors may occur. Thus, if during a flight in one direction the wind speed is 1 m.p.h. more than during the return flight in the opposite direction, an error of $\frac{1}{2}$ m.p.h. is caused.

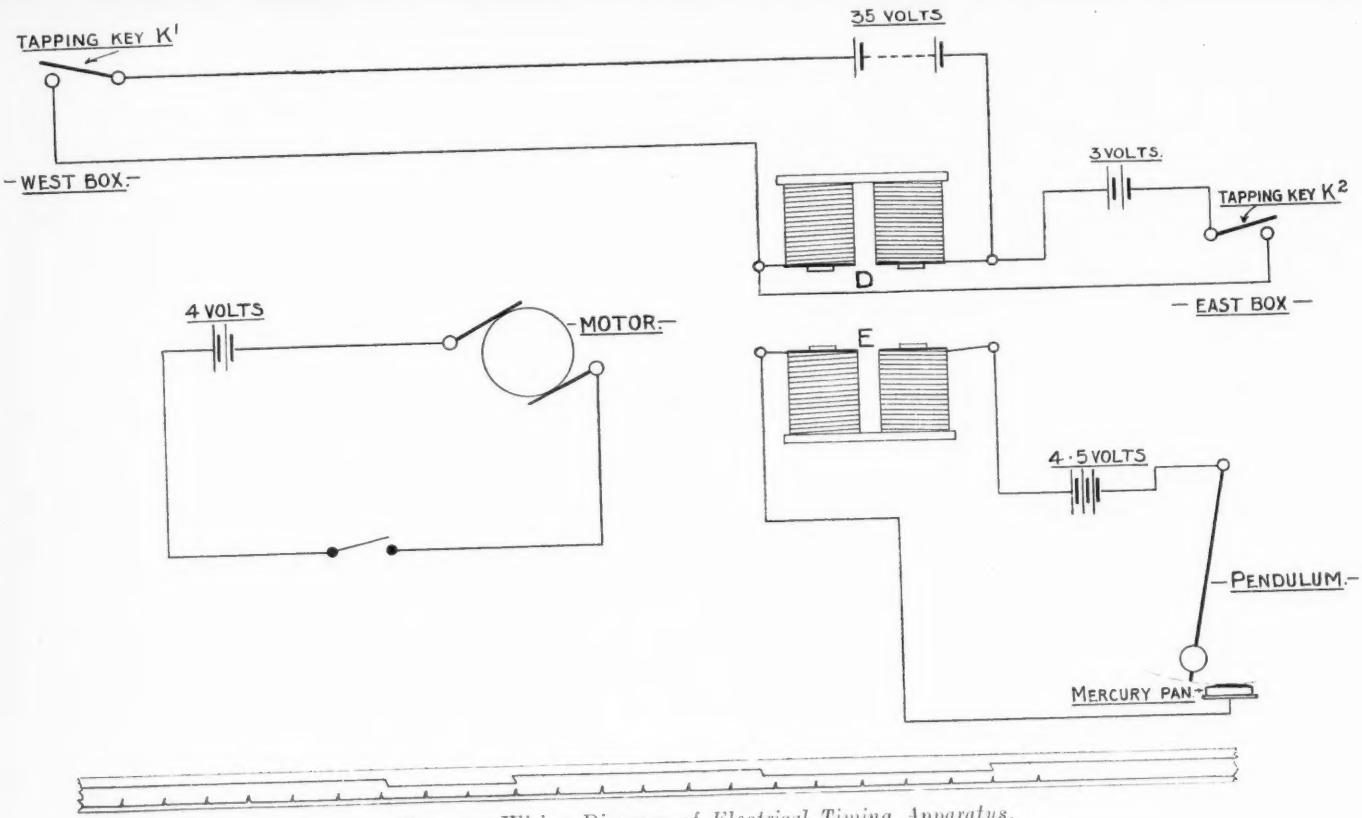


FIG. 7.—*Wiring Diagram of Electrical Timing Apparatus.*

This error may be caused either by variations in the wind itself or by the aeroplane flying at a slightly different height above the ground. Consequently it cannot be eliminated, and speed measurements in a wind which has an appreciable component of velocity up and down the course are not likely to be very accurate. Speed course trials at Martlesham Heath have been confined to occasions when there was no appreciable wind along the course.

Camera Obscura System for Speed Tests.

The principle of the apparatus is well known, but the actual calculations involved in the practical use may perhaps be worth while detailing.

The system consists of two lenses situated at the ends of a given base line (Fig. 8). One lens A has its optic axis vertical, and the optic axis of the second lens B lies in the vertical plane containing the optic axis of A, but is inclined towards A at some convenient angle to give a suitable field of observation. A convenient angle is 45°. The lenses should be of the order of 20 to 24 inches

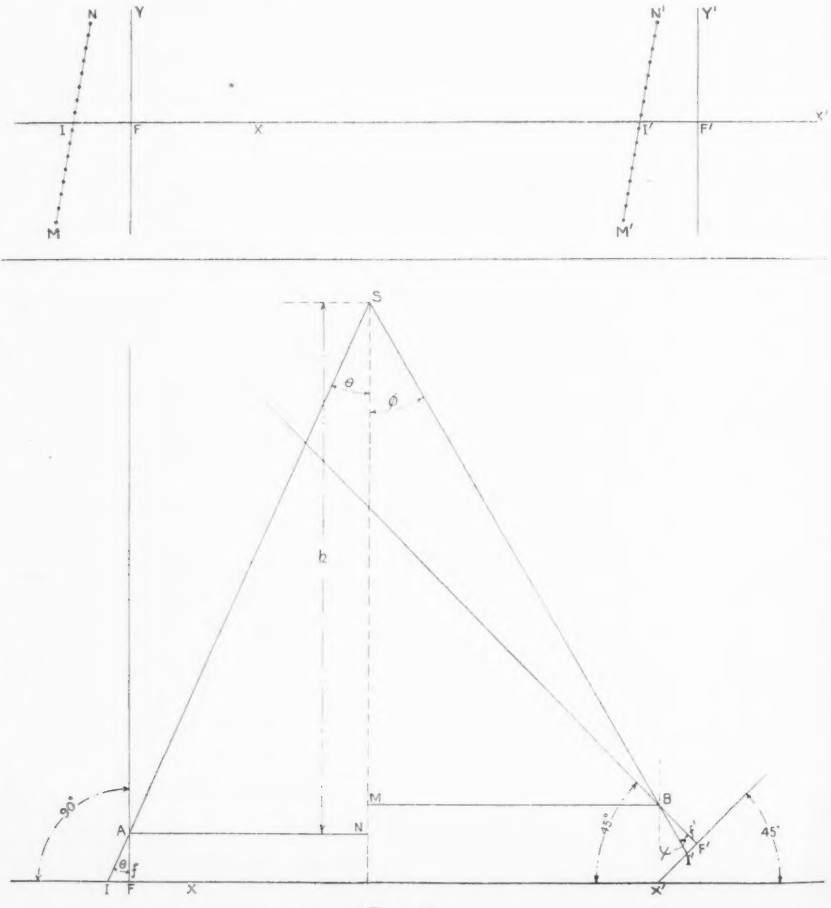


FIG. 8.

focal length and very carefully calibrated optically. In the case of each lens, a plane dead-level slate slab is adjusted so that its surface coincides with the focal plane of the lens. On each of these surfaces through the focal point of the lens are drawn two mutually perpendicular straight lines, one of which is the trace on the surface of the vertical plane containing the axes of the two lenses. In the upper part of Fig. 8 these axes are shown, F being the focal point of A and F^1 the focal point of B. The image of an object crossing the field of view of both lenses will obviously cut the axes Fx and F^1x^1 simultaneously, and from the measurements of the intercepts of the image on Fx and F^1x^1 the time height of the object can be found by means of ordinary trigonometrical equations.

Thus, if L feet is the distance between the lenses, and one lens through the contour of the ground is Y feet above the other h, the height of the object

$$= \{ L + Y \tan (45^\circ - \phi) \} / \{ \tan \theta + \tan (45^\circ - \phi) \}$$

are calculated from observations on the surface charts since $\tan \theta = FI/f$ and $\tan \psi = F^1I^1/f^1$.

If an aeroplane flies along a straight horizontal path over the system so that the path can be traced in the table charts of both lenses and the rates at which the images travel measured, the true ground speed of the aeroplane at that height is calculated from the height and focal length, *i.e.*, time ground speed $= hv/f$ where v = rate of travel of image.

In practice the observers in the camera huts are in direct communication by telephone, and in parallel with telephone circuit is placed the electric seconds pendulum circuit already described in connection with the ground speed course, thus enabling observers to hear synchronous second "clicks."

The pilot flies the aeroplane straight and level at a height between 3,000 and 5,000 feet, according to the maximum speed, in a direction as near as possible at right angles to the plane containing the optic axes of both lenses. The observers in the camera huts plot in the path of the image by dotting its position at intervals of one second as shown by MN and M^1N^1. To enable the wind speed at that height to be calculated Very smoke cartridge is fired, the path of the smoke cloud image being dotted in by a second observer. Similar flights are carried out at various air speeds. The ground speeds can thus be calculated; also time speeds by correcting for the wind. The pilot takes the readings of A.S.I. aneroid and atmospheric temperature during each run. The correction for the air speed indicator is then deduced as in the case of calibration over the ground speed course. Fig. 9 shows a copy of a chart from the camera obscura, but with lens vertical.

(4) Climbing and Speed Test.

Flight tests to determine the climbing qualities and speed of an aeroplane are invariably carried out together, the procedure being as follows:—The aeroplane, loaded to the specified total weight for the test, is climbed at full throttle at the best climbing speeds already found, up to the service ceiling (100ft. per min.) or 17,000 to 18,000 feet, if this is lower than the service ceiling. In cases of scouts, higher altitudes are of course necessary and due provision must be made for oxygen and heating apparatus. Having reached the end of the climb, the aircraft is flown level at a series of heights on the descent, which should not be too rapid as to cause undue cooling of the power system. The required data are obtained from (1) pilot's and observer's readings, and (2) recording instruments. First dealing with the readings to be noted, it will be agreed that for a single-seater scout aeroplane they are rather formidable and readily show one of the reasons why a test pilot requires training.

(1) Atmospheric Temperatures.

These are read from a strut thermometer fixed clear of any propeller slip-

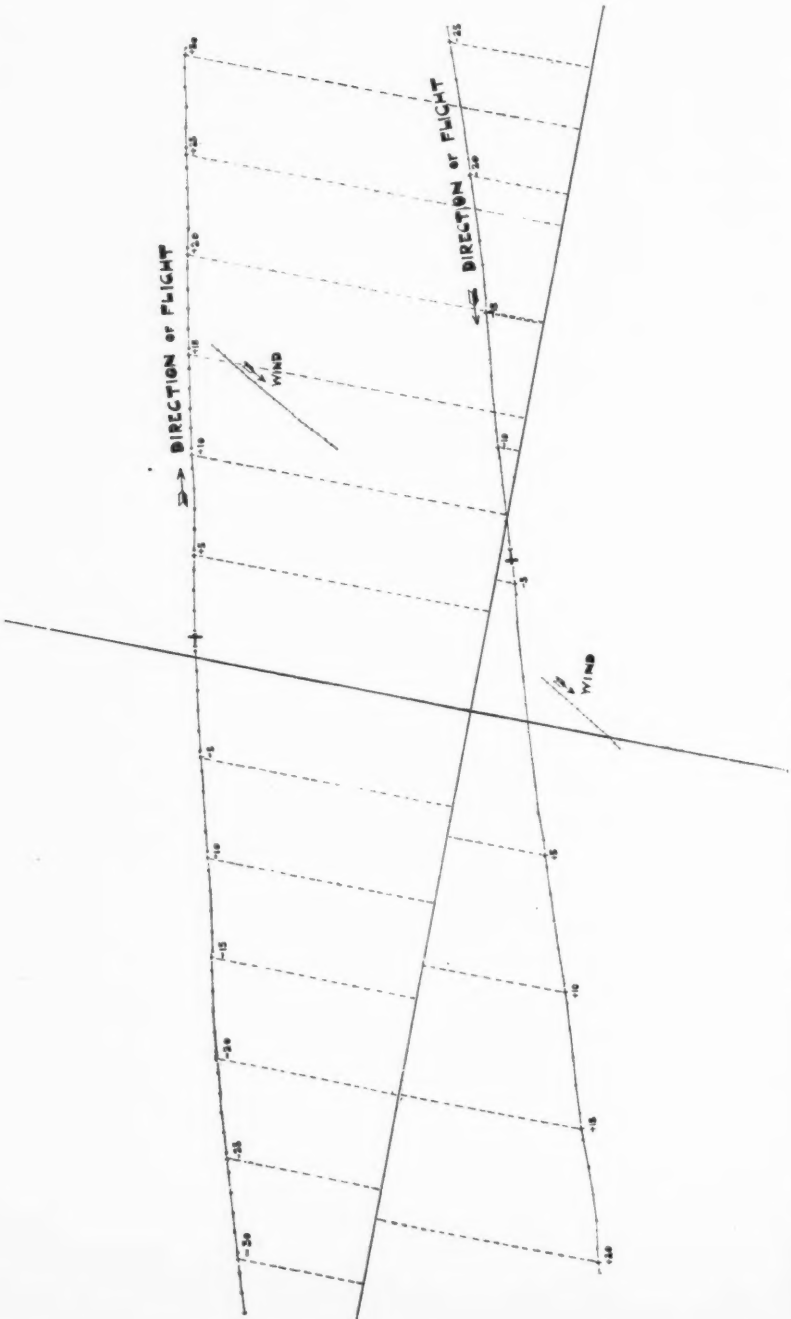


FIG. 9.

stream, or from a vapour pressure thermometer, which allows the capillary tube to be led to a dial in the cockpit. The advantage of the latter is clear—the pilot or observer does not have to move his head and re-focus his eyes from the other instruments in the cockpit. Also a larger scale is possible and observation errors are reduced to a minimum. Readings are taken from ground level and every 1,000 feet up to the end of the climb, also at the level speed heights on the descent. Calibration of these thermometers is somewhat difficult for the low readings, and cannot be done with the ordinary plant available at an aerodrome. Lag, of course, is important in the case of fast-climbing aeroplanes; if a strut thermometer is used and we can only approximately allow for this by

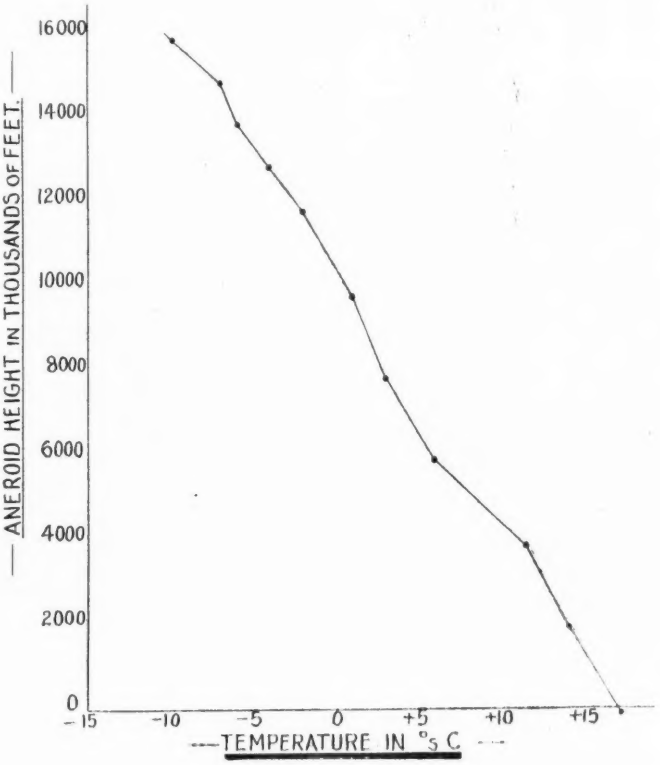


FIG. 10.

D.H.9a 400 Liberty. Temperature Reading for Test.

observing the rise of temperature when flying level at the end of the climb and noting time until steady, the lag is rarely more than 0.5 of a degree. An alternative way of noting temperatures on a descent at the same rate is open to the objection of general change in temperature of the atmosphere effecting the results; also it is practically impossible to guarantee passing through the same atmosphere. Fig. 10 shows the temperature readings of a test climb plotted against aneroid height.

(2) Aneroid Height.

The heights every 1,000 feet are noted against stopwatch. The instrument used is the standard R.A.F. altimeter calibrated before and after the trials in a vacuum chamber against the standard scale mercury column. As the aneroid is used as a pressure instrument, this means that the height scale is fixed and, according to the variation of the barometer, the reading above or below should be noted, although this can be checked against the ground recording barometer reading at the time of beginning the climb.

(3) Air Speed from the A.S.I.

The standard R.A.F. pattern A.S.I. and pitot head is used calibrated for instrument errors and pitot corrections as previously described. Readings are taken every 1,000 feet in the climb and during level speed tests. These latter

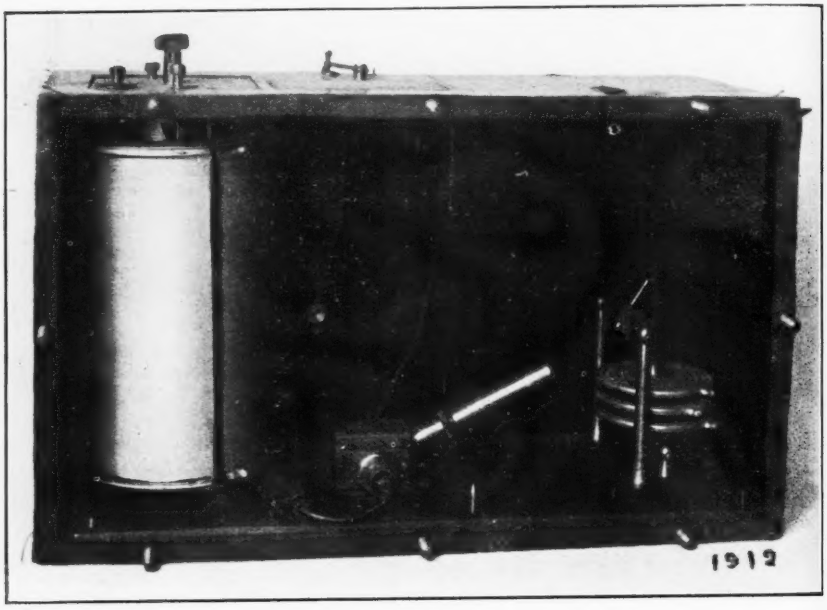


FIG. 11.

should be of not less than three-minute duration, preferably longer, and must be level. A check on this will be observed on the recording instruments which will be described later. To help the pilot, the Wright Bubble Statescope is fitted. This extremely useful instrument is very necessary when a far horizon or clear distant cloud edge are not visible. In order to counteract any air currents with a slight fall or rise, the climb should be carried out in a large diameter spiral path of the order of five miles.

(4) Other readings are taken every 1,000 feet and during level speeds are: Engine r.p.m., radiator temperature, oil pressure, position of radiator shutters or blinds or of radiator if of hinged type. This latter is recorded by noting control position on a scale marked to correspond with definite positions of the shutters on radiator, care being taken for pressure to be applied to the shutters to take the place of wind pressure in actual flight.

At the present stage of instrument development, recording barographs and air speed indicators are the only two which can be used with any degree of accuracy. Recording air and radiator thermometers and revolution indicators are still only in the experimental stage. At the same time, I am a firm believer in both observed and recorded readings, as even the most reliable reading instrument may fail during an important part of the tests.

Two types of recording barographs have proved satisfactory for aeroplane testing—the small pocket design by Richard of France and the box variety, giving a much larger scale. The scale of the pocket size is usually 5.5 cms. for 20,000 feet with time 2.3 cms. per 30 minutes. The total size of the instrument is 5in. by 3½in. and of chart 3½in. by 2½in. So it is quite possible to carry several, usually three, on a climb. As the pen movement is slow, in order to prevent a thick line being recorded due to the ink running, etc., the clockwork

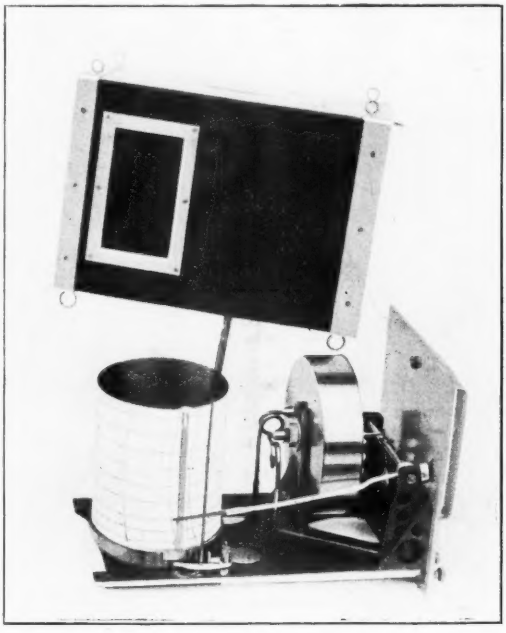


FIG. 12.

raises the pen once every 7 seconds; thus the recorded line is really a series of fine dots. The height scale is calibrated before and after the test climb, ascending and descending. Other calibrations include clockwork test by running for 30 minutes and noting time scale; and pen swing in case the chart has not been placed in position dead true. Extremely accurate readings can be obtained from these charts by photographic enlargements.

The larger type of recording barograph, giving consequent greater accuracy of observations, presents no special features and follows the design of the usual recording atmospheric barometer. Apart from the pocket Richard, all recording instruments are necessarily subject to vibration, which must be guarded against by suitable shock-absorbing suspension or mounting. All also are subject to backlash, and the link motion has to be constantly examined and adjusted. To

overcome the latter defect, an interesting instrument has been designed by Prof. S. Smith (of Alberta University, Canada) when a Captain, R.A.F., on the Technical Staff at Martlesham Heath. This is shown in Fig. 11. The principle consists of a spot of light being focussed on to a small mirror suspended axially and moved by the rise and fall of the aneroid boxes. The reflected light forms a record of this movement by shining on to a photographic sensitised paper revolving on a drum. The absence of the usual complicated link motion, pen friction and bearing friction practically eliminates all backlash and reduces lag to a minimum.

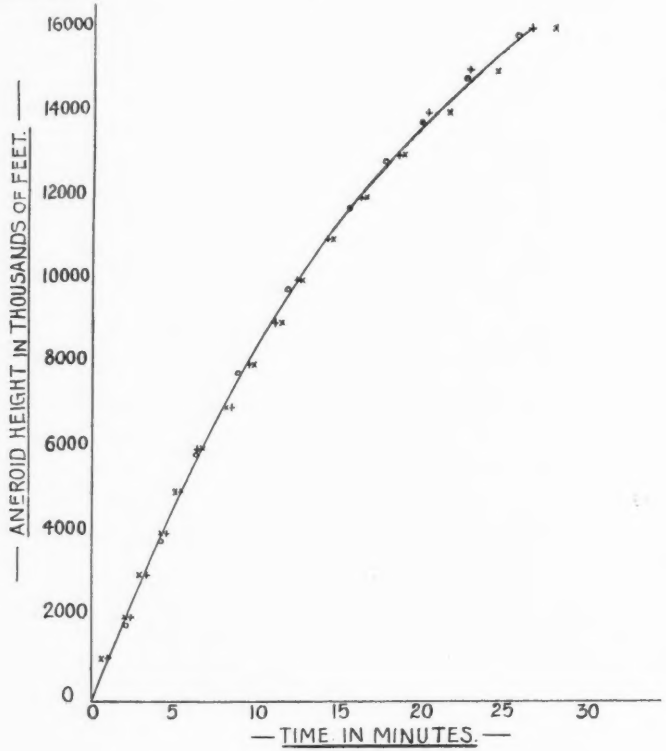


FIG. 13.
D.H.9a 400 Liberty. Aneroid Height—Time Curve.

Recording air speed indicators are constructed on the same principle as the recording barograph, the recording mechanism being operated by movement of the diaphragm of the differential pressure box. An example of this type is shown in Fig. 12, designed and constructed by Messrs. Munro.

Having obtained all the necessary data from the flight tests, the reduction to standard atmosphere is a matter of routine calculations.

The first stage is to plot aneroid height against stopwatch time and recording barograph heights against their time. It is usually found all these agree very well, and a mean curve is drawn which will average all errors of observation. Such a curve is shown in Fig. 13. From this, aneroid rates of climb are obtained by taking tangents at every 1,000 feet. This rate of climb must then be multiplied by the aneroid correction factor corresponding to the atmospheric temperature

recorded at that height, thus giving a time rate of climb. Using the density curves previously described, the standard heights, corresponding to the aneroid height (or pressure) and temperatures are read off. True rates of climb are then plotted against standard height as shown in Fig. 14, which is typical and gives the results of three test climbs worked out in this manner. The mean rate of

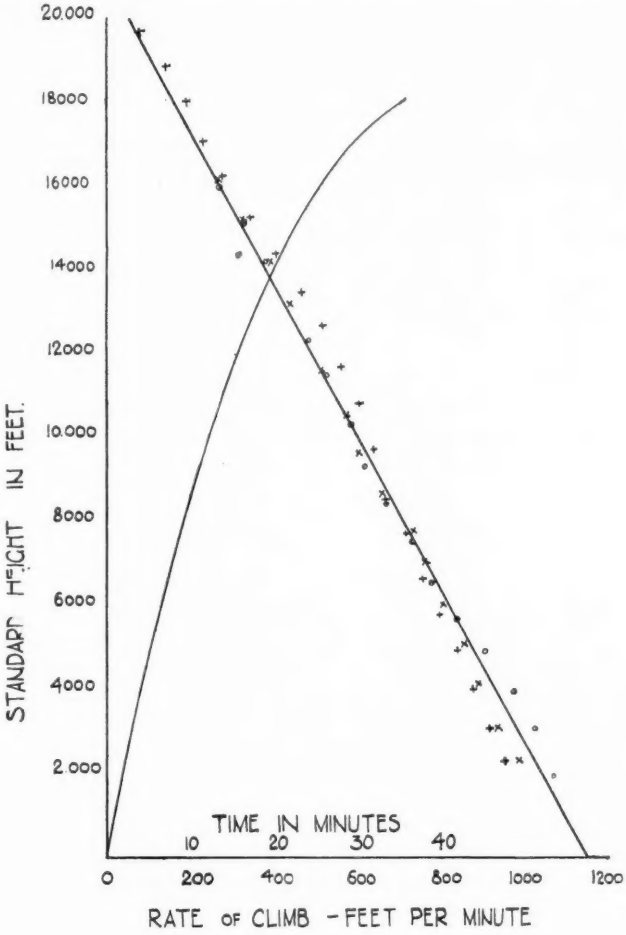


FIG. 14.

D.H.9a—400 Liberty. Rate of Climb and Time to Height.

climb curve is in nearly every case a straight line. The ceiling is given by its projection to the height ordinate. By simple integration a formula is developed for the time T to any height h.

$$T = 2.3 \tan \theta \log C/(C - h)$$

where C = ceiling height, θ = angle of slope.

If the rate of climb curve is not a straight line, possibly curving away slightly at the top or bottom, the reciprocals of the rate of climb are plotted for

each thousand feet, and a mean curve is drawn through the points obtained. The time to any height is then given by the area enclosed by the horizontal ordinate at this height. From this time to height curve all particulars of climb for any height can be read off as required.

The reduction of A.S.I. observation or self-recording instrument readings to true speed is straight forward, as the speed course correction factor has already been obtained, also the standard height and density. The A.S.I. standard

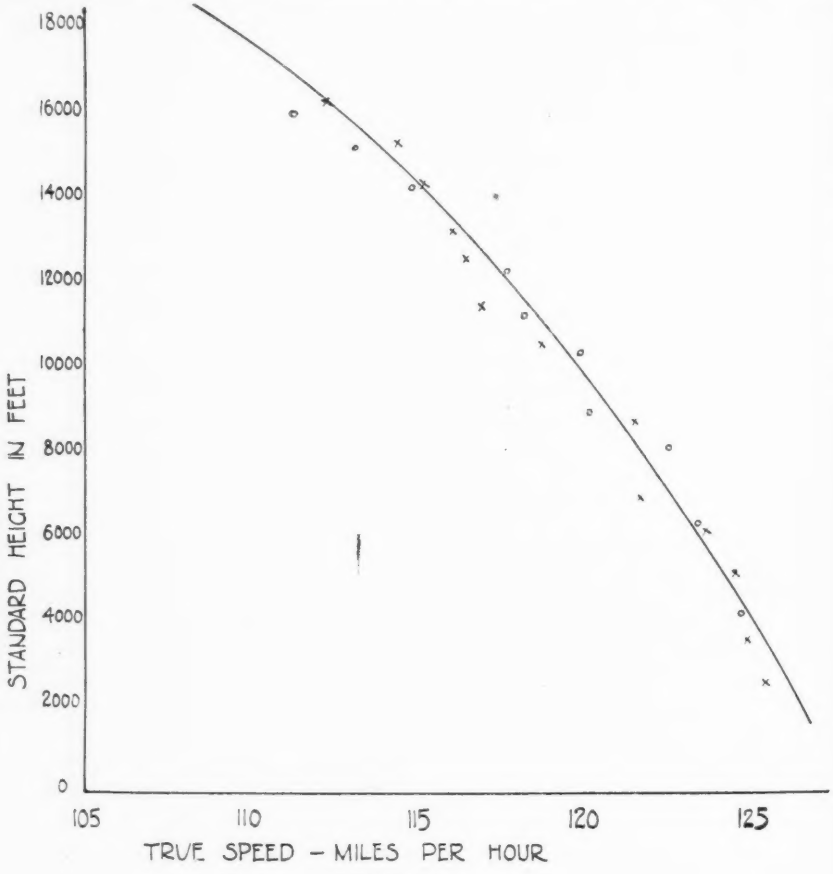


FIG. 15.

De H.9a 400 H.P. Liberty. True Speed at Heights.

density is .004 less than our adopted standard density of 1.225 kilo. per cubic metre, but this is not sufficient to affect the results appreciably. Thus it is only necessary, after applying the correction factor, to divide by the square root of the density at the height in question to obtain the true speed.

True speeds are plotted against standard heights from three or more test flights, and a mean curve drawn from which speeds can be quoted, possible errors due to piloting, weather conditions and observations being averaged.

Figure 15 shows results of three tests and the final curve.

FIG. 16.—*Petrol Flowmeter.*

(5) Miscellaneous Tests.

Consumption Trials.—Fuel consumption of aircraft is most important from a military point of view. In civil aviation the range of an aeroplane is not cut so fine, the bench tests of an engine giving sufficient data for determination of safe flying distance without replenishment of fuel.

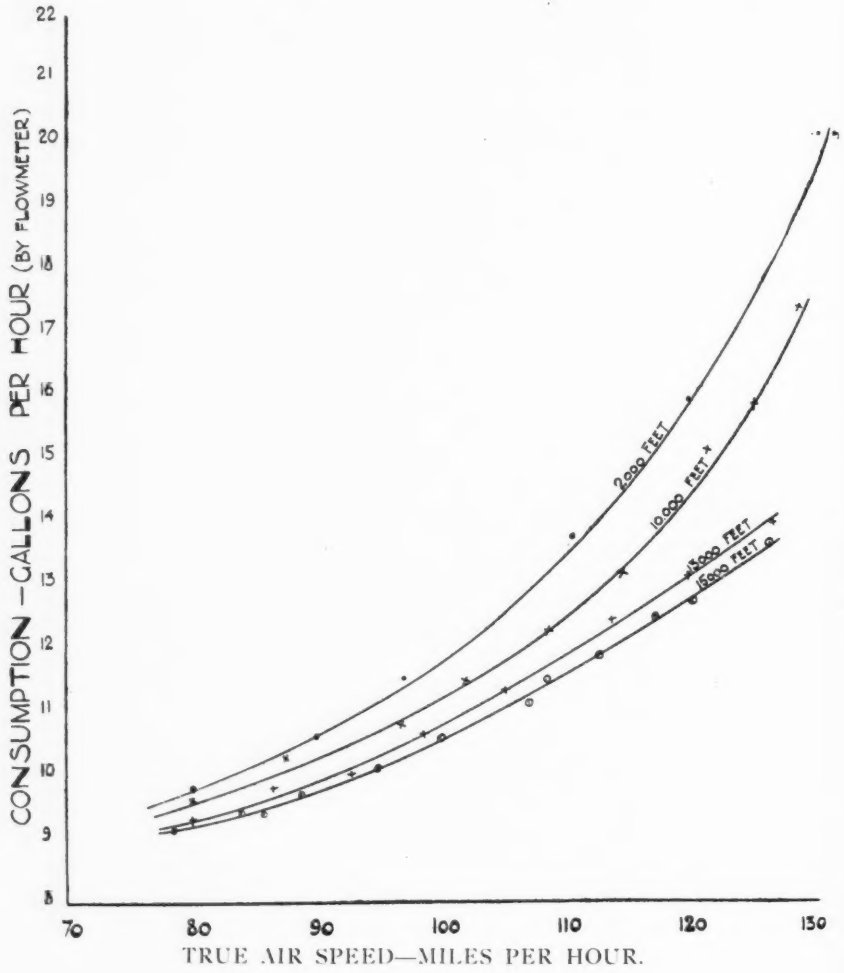


FIG. 17.

Series of Consumption Curves. 300 h.p. Hispano Suiza.

In the case of Service aircraft, however, it may be necessary to carry out bombing or reconnaissance duties at limit distances. Actual consumptions are then of great help in preparing for such duties. Take the case of a long-distance bombing aeroplane, the consumption on the outward and homeward journeys to the objective varies considerably, with height, load, and speed. If,

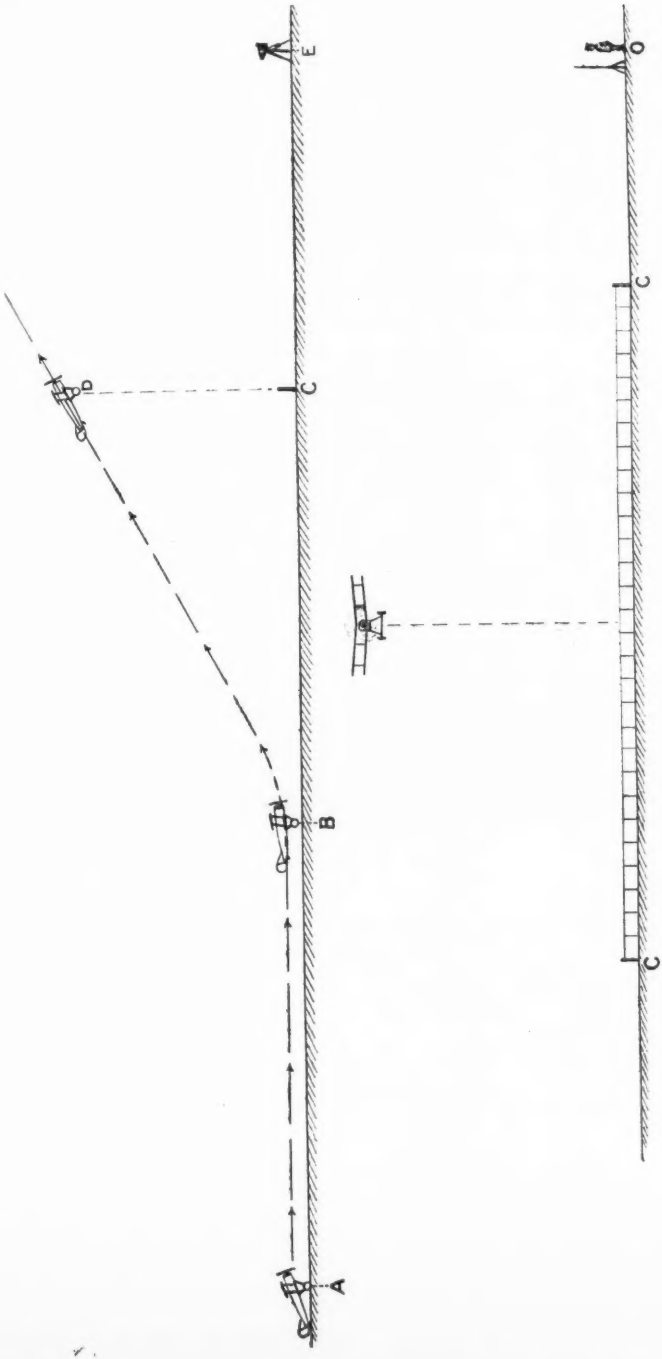


FIG. 18.—*Getting-off Tests.*

therefore, one knows, for instance, the most economical speed and consumption of the aeroplane, (1) fully loaded, (2) medium load, e.g., no bombs and half fuel; (3) light three-quarter hour's fuel, at various heights, it is possible (subject of course to meteorological conditions) to plan the whole flight on its most economical basis.

Consumption trials to give this data are therefore straight level flights at various air speeds (usually five, varying from slowest speed to fastest speed) at suitable heights, say 5,000, 10,000 and 15,000. Each test must be of at least five minutes duration to enable the power unit, and also the instruments, to have settled down to the change. The actual consumptions are taken by a flowmeter, which can be calibrated to read direct gallons per hour or preferably lbs. per hour, so that variation in specific gravity of the fuel can be allowed for. One type is shown in Fig. 16.

This consists of a circular passage for the flow of petrol, which gradually increases in size from the in port to the out port. The pressure of this flow moves

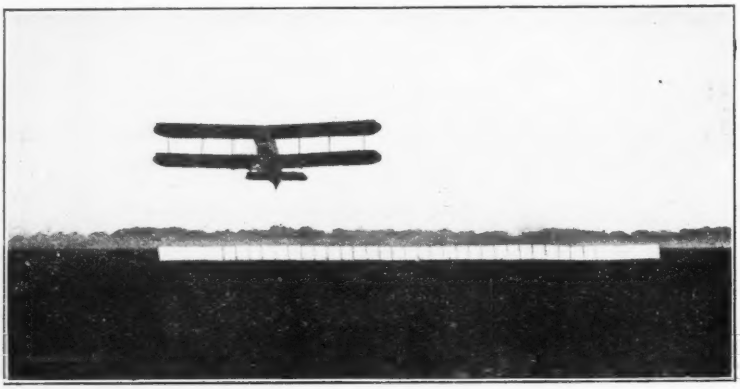


FIG. 19.

a light vane fitted to a central axis and rotating against the action of a coiled spring. The farther the vane moves, the larger the opening.

The same principle is adopted in the gravity type flowmeter, in which the graduated passage is obtained by fixing a taper inside the tube, the flow raising a ferrule against gravity.

Both instruments are liable to many errors in actual flying, the difficulty being to obtain steady and consistent readings with accuracy.

Consumption curves from results obtained by this type of flowmeter are shown in Fig. 17.

Getting off and Landing Tests.—The performance of an aeroplane with respect to its getting off and landing powers, assumed importance with the development of civil aircraft after the war. This was officially recognised, and special tests were incorporated in the schedule of the Civil Aviation Trials of 1920, held at Martlesham Heath. The methods then devised for the tests have now been adopted as part of standard performance trials of any aeroplane except scouts and high-powered two-seater fighters. All these tests depend so much on the wind that they are not attempted in any wind over 5 m.p.h.

Getting off Tests (Land).—The problem was to obtain the height of the aeroplane to an accuracy of 0.5 of a foot at a definite distance away from the starting point, the idea being that the aeroplane was supposed to be taking off either from a forced landing, or a very small aerodrome with trees, houses, or other obstacles which had to be cleared. The arrangement is best seen from Fig. 18.

Here CC is a canvas screen about 3ft. deep and 100 ft. long, marked off with narrow black strips every 3ft. The scale side faces a camera E, the lens centre of which is levelled on to the base of the screen, *i.e.*, ground level. The shutter of the camera is electrically released by an observer O stationed in the same line as the screen at such a distance that he can sight an aeroplane as it passes over the screen. From the scale CC it is thus possible to determine the height of the aircraft as it passes over the screen by measuring up the photographic negative.

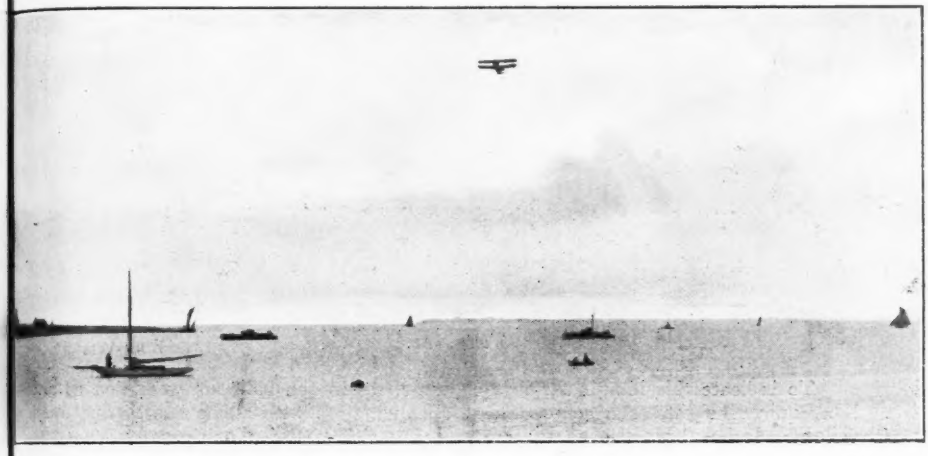


FIG. 20.

If this is done with a travelling microscope, extreme accuracy can be obtained. If the ground is suitable between A and C, it is possible to spot the point of take off from the wheel tracks, thus affording further data as to slope of climb in taking off. One point requires special attention, the lag between the tapping key of observer O and actual release of the shutter must not be large. It can be measured by taking a photograph of a swinging pendulum, using the actual apparatus and length of cable. In practice it was found that pressing the key just as the front of the aircraft appeared in the sight gave an actual image of about the centre passing over the screen. Fig. 19 shows the "Westland Limousine" passing over the screen during trials.

Getting off Tests (Sea).—The same principle is adopted, but the same degree of accuracy is not obtained. The scale is represented by two mark boats, anchored a definite distance apart. In line with these is the observer and sight, who has to be on shore or a pier for steadiness. By means of a signalling lamp, the instant the flying boat or seaplane passes over the scale line is flashed to the recording camera, which must also be on shore or a pier. It will be seen that more errors are liable than in the case of testing aeroplanes, but as results are only for comparative purposes and not for clearing a definite object, this does

not matter. Fig. 20 is a photograph of the Vickers "Amphibian" undergoing a test in this manner.

Landing Tests.—This resolves itself in the measurement of the distance required for the aeroplane to pull up dead or slow enough to turn after clearing an object of a definite height. It is obvious for test purposes these objects must not cause any obstruction to flying, in case the pilot flies below test height.

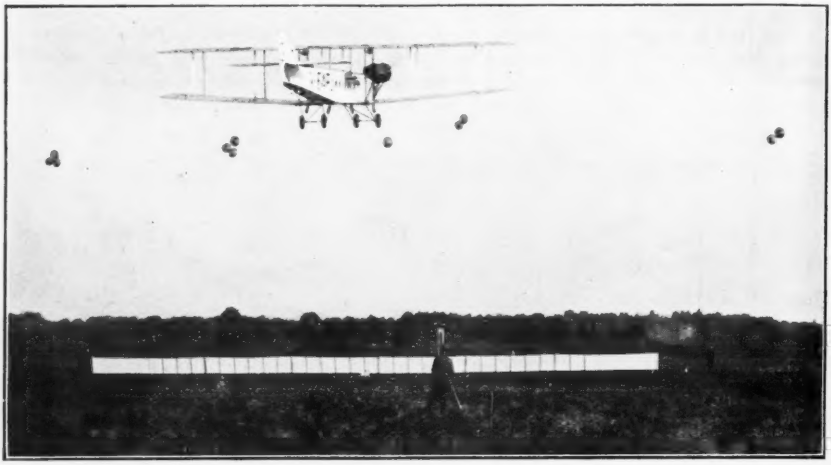


FIG. 21.

To indicate this imaginary obstacle, small hydrogen balloons were floated at the required height, each being on a minute windlass with a fine height line and weight. It has been proved that there is no risk if the pilot does fly into the balloons or twine. Having cleared the balloons, the actual point of pull up must be spotted by observers. To save long measurements the aerodrome, in the case of the civil trials, was accurately surveyed and three circles marked out with numbered calico strips pegged on the circumference every five degrees. It was then only necessary to refer by measurement to two or three of the strips nearest to the observed point. This test also affords means of trying out braking devices. Fig. 21 shows the Handley Page clearing the line of balloons before landing.

PROCEEDINGS.

EIGHTH MEETING, 57th SESSION.

A meeting of the Society was held in the rooms of the Royal Society of Arts, John Street, Adelphi, London, on Thursday, February 16th, 1922. In the unavoidable absence of the Chairman, Lieut.-Col. O'Gorman, Major-General Sir W. S. Brancker presided, and introduced Squadron-Leader C. F. A. Portal, D.S.O., M.C., who is an instructor at the Cranwell Cadet College, in Lincolnshire.

Squadron-Leader PORTAL then read his paper on

METHODS OF AEROPLANE FLYING INSTRUCTION.

I must begin by confessing that when I received the kind invitation of the Royal Aeronautical Society to read a paper on the methods of aeroplane flying instruction, I had grave doubts as to whether I could make it either informative or interesting.

In the first place, by comparison with others on which papers have been read here, this subject seems "cut and dried." I do not mean that flying instruction has reached such a pitch of excellence that further improvement is impossible, but that as far as the Royal Air Force is concerned the present methods are stereotyped in certain orders which the service instructor has to obey.

Secondly, I fear that a great many of those present know almost all that there is to be known on the subject, and I must ask them to be patient when I travel laboriously over ground which is very familiar to them.

I shall confine myself as much as possible to the practical side of the question as it presents itself to the instructor to-day. I expect that much of interest might be said on the historical, theoretical and medical aspects of the subject, but I fear that if I ventured to leave the firm ground of modern practice I should speedily find myself hopelessly bogged.

In the year 1915 (I cannot speak from personal experience of earlier times) there were two types of school at which the pupil might, if he were lucky, learn to fly. A brief description of the methods used at each will help us to realise the improvement which has taken place during the last six years.

The more advanced schools had dual control aeroplanes, usually Maurice Farmans, but in most of them the duplication of the controls was very primitive and inefficient. The instructor generally sat in the pilot's seat with the pupil behind him. There was no standard system of teaching, and each pilot went about the business in his own particular way.

What he generally did was to fly round with the pupil's hands on the controls until the latter had some idea of the movements necessary to execute turns and had visualised the correct position of the aeroplane under the various conditions of flight. The best instructors then put the pupil in the front seat where he could see ahead, work the rudder properly and use the instruments. Great importance was attached to the air-speed indicator, and the different speeds for taking off, climbing, level flight and gliding were learnt by heart. After a few landings (done by the instructor as a rule, the pupil's hands being on the controls)

and still fewer words of advice on the management of the engine, the time arrived for the first solo flight.

These "first solos" were often terrible sights. The responsible instructor had, of course, to watch the proceedings, but everyone else usually retired out of sight. Well they might, for any small misfortune (from the sudden appearance of a lorry on the road across the aerodrome to the awakening of a dormant earwig within the pitot tube) was enough to cause disaster.

Some instructors were cleverer than others and taught their pupils better and more quickly, but I do not think that any two of them worked on the same lines. A great many, and among them were the leaders of the great "Instructional Revolution" of 1916-17, were themselves perfect pilots on the aeroplanes of the time, but not one of them had formulated any proper system of teaching.

Whatever success attended the pupil taught by the average instructor of the period depended on his ability to imitate. It was not until he went into the air alone that he began to acquire any real knowledge, and this often had to be bought at the price of several undercarriages. The experience and confidence of most pilots was limited, and in some cases the instructor occupied, throughout the dual control period, the seat from which the unfortunate pupil would be called upon to control the aeroplane on his first solo flight. Since the pupil's safety depended upon his ability to visualise the correct position of his aeroplane in turns, glides and landings, it is clear that a sudden change of view-point just before the first solo flight was a very serious matter.

There were at this time certain schools which taught on quite different lines. Here the pupil received a good deal of verbal instruction on the ground, but was from the first alone in the aeroplane. Beginning with an aeroplane fitted with an engine too weak to lift it into the air, he was encouraged to run about in it on the ground until he became proficient in the use of rudder and engine controls. He was then promoted to a more powerful mount, and gradually learned to perform "hops," "straights," and finally landings and turns.

There was probably more to be said for this method at the time than the modern instructor might suppose. The pupil sat in the same seat throughout, worked his own engine, and above all knew from the start that he must work out his own salvation. Though his methods might be unconventional, he rapidly gained confidence in himself. These advantages are only appreciated when the state of contemporary dual control is remembered; the greatest advantage which the dual control schools enjoyed lay in the fact that they were more independent of weather conditions.

Towards the end of 1916 came what I have referred to as the "Instructional Revolution." I hope I have succeeded in showing that the instructional methods of 1915 were, to say the least, far from perfect. The chief causes of inefficiency seem to have been, in the first place, want of confidence and experience on the part of instructors, and secondly, the absence of any real system in the methods employed.

The organiser of the new school which was to revolutionise the whole aspect of flying instruction appeared to base his system upon three facts, which up to that time had scarcely been realised. He maintained, rightly, that (1) A properly designed aeroplane could be safely put into any position provided that it was at a sufficient height to enable it to right itself and gather speed without hitting the ground, and that pupils should not be taught on craft which were not properly designed. (2) There was only one way to perform any manœuvre correctly, though it could be done incorrectly in many. The habit of flying correctly ensured safety under all conditions. (3) The movements necessary to perform any manœuvre correctly were capable of clear analysis and simple explanation.

Anyone who has learned to fly since 1916 probably thinks that the knowledge of these facts is as old as flying itself, but I myself remember being told by the best instructor in my station that it would be unwise to stall an Avro as one never could be sure of getting out of the nose-dive; I also remember, in 1916, seeing an Army Commander and several senior R.F.C. officers who had come miles to witness a display of "stunting" by one of the French "Aces"; everyone present thought the performance wonderful, and the pilot was overwhelmed with congratulations, though what he did has been done in my presence by a pupil on his first solo flight.

The policy of the new "Instructors' School" was as follows. The staff was carefully selected from officers who were able to fly perfectly themselves and at the same time had the gift of being able to teach. A standard method of instruction was adopted, which has remained practically unaltered for five years and will be dealt with later. To enable pupil and pilot to communicate freely in the air a telephone was introduced, by means of which each movement could be explained and every fault corrected.

Now for the first time the young pupil had everything simply and carefully explained to him. Instead of having the control lever snatched from his hand whenever he made a mistake, he would hear his instructor speaking calmly to him and telling him what was wrong and what to do. Nor was the effect of the new system limited to mere proficiency in flying. With understanding came confidence and the gradual realisation that, provided the ordinary rules are observed, flying is as safe as any other form of locomotion. In an incredibly short time the leaven from the first instructors' school had permeated the whole service, leading to a vast improvement in flying ability and moral.

I will now try to describe more fully the actual method of instruction used. I should first say that the Avro with 100 h.p. Mono engine was adopted as the standard elementary training aeroplane at the end of 1916; though the system to be described was devised primarily for the Avro, it is applicable to almost any single-engined tractor.

The pupil gets into the back seat, is connected by telephone to his instructor, and is taken up to a height of about 1,000ft. He is first told that he must sit at his ease with his muscles relaxed, his heels on the boards provided for them, and his insteps touching the rudder bar lightly. Many pupils get into the habit of sitting rigid and immovable, like a criminal in the electric chair; this is not conducive to good flying, and should be corrected at the start.

The "patter" used by the instructor in the first lesson is something like the following, and may be taken as a specimen of the whole. Having explained that there are three controls operated by the pilot in flying, he continues:—

> "When the control lever is pushed forward, the elevator is depressed. The air, striking the under side of it, raises the tail and depresses the nose." (Here he pushes the lever forward to illustrate.) "When the lever is pulled back, the elevator is raised; the air strikes the top of it, depresses the tail and so raises the nose." (Again the fact is demonstrated.) "When the control lever is pushed over to the right, the left ailerons are depressed and the right raised; the air strikes the under side of the left aileron and the top of the right ones, raising the left and depressing the right wing."

The use of the rudder is explained in the same way. I only give the above example to show the extreme simplicity of the language used and the fact that nothing is taken for granted.

To describe in detail the teaching of each particular manœuvre would need several papers of this length. I will merely give an outline of the course, showing the order in which the subjects are most conveniently taken and the average time required for each of them.

The pupil has had the effects of three controls, used singly, explained to him. The next step is to give him entire control, telling him to keep the top of the cowl level with the horizon, the wing tips level with one another, and the nose pointing to some distant landmark. This is generally called "flying straight and level." At first the pupil can only remember to use one or two of the three controls at the same time. His wing tips may be level and his cowl on the horizon, but his nose will then swing round to the left. He corrects this with the rudder, but now his nose is too low; he pulls it up to the horizon again, only to find that he has let his left wing drop. This goes on for a few minutes, but generally within a quarter of an hour he is able not only to keep his course on a level keel, but to return to it after the pilot has disturbed it by a sudden movement of the controls.

The instructor avoids as much as possible any interference at this and all other stages, merely telling the pupil quietly what to do when necessary.

When the novice can fly straight and level satisfactorily, he is shown the climbing and gliding angles of the aeroplane, and is told to note mentally the apparent distance between the top of the cowling and the horizon in each case. He is shown both the proper climbing angle and also the maximum angle at which the aeroplane will fly, and has his attention drawn particularly to the diminished effect of the aileron control as stalling point is reached. This concludes the first lesson, the time occupied being about half an hour. Pupils rarely derive any benefit from the last part of a longer period than this.

The next lesson consists of revision of the first one and demonstration of the way to make a 45deg. turn. As a rule only two turns are taught, one with a bank of 45deg. and the other nearly "vertical," say about 80deg. Three points should be explained on the ground before this lesson begins. First, that the use of each control is to turn the aeroplane about a certain axis, whatever may be its position with relation to the ground; secondly, that as the outer wing travels faster on a turn than its fellow, it will tend to rise; thirdly, that the nose of the aeroplane will tend to rise on a left-hand and drop on a right-hand turn owing to the gyroscopic effect of the engine.

Once in the air, the novice will forget this, but he should be told it notwithstanding. The proper combination of the controls necessary to make a sustained turn with the cowl on the horizon and the diagonal bracing wire in the centre section horizontal is not, as a rule, very quickly learnt; three lessons of half an hour each are generally necessary. The pupil is next taught to turn on the climb and glide, for which one lesson is usually enough; the principle is the same as for ordinary turns and it is only necessary to use the elevator and rudder rather more coarsely in gliding to compensate for the absence of slip-stream.

The two following lessons may be devoted to steep turns, and here again some trouble may be expected. It is not at all easy to make a steep left-hand turn accurately on an Avro 504K, and the pupil generally stalls repeatedly and may have his first experience of a spin; if this happens, the instructor merely tells him what to do to get out of it.

In the next three lessons the pupil is shown how to make loops, half-rolls and spins, and is taken quickly over all the ground which has so far been covered.

Up to this point about five hours have been spent in the air, and the novice should now be able to execute accurately all the manœuvres of ordinary flying. He has been taught up to now to regulate his movements almost entirely by the position of his cowl with regard to the horizon, deriving also a certain amount of help from the "feel" of the controls and the intensity of the sound made by the passage of the aeroplane through the air.

In the lessons which follow he is taught no new manœuvres, but has to develop what is generally termed his "judgment." He has not only to learn

to take off and to land properly, but also to foretell accurately where his aeroplane will come to rest, to note the direction of the wind and to glide at the correct speed when he is too low to use the horizon.

Taking-off is generally learnt very easily, but landing is far more difficult.

At first the instructor explains the principle, and then does a few landings himself with the pupil's hand lightly holding the control lever. The difficulty which most learners experience is in estimating the height of their wheels from the ground; but even when this has been mastered the method of getting the tail down as the aeroplane loses speed takes a long time to teach, and there is often a tendency to abandon the rudder through over-concentration on the elevator. The ability to land well from the start is not found in more than one pupil out of ten, as a rule, and with one out of every five it may be necessary to continue the instruction on this subject for ten or twelve hours before any proficiency is attained. Most pupils can be trusted to land without accident after three or four hours' teaching.

The instructor's great difficulty is that he cannot here allow the pupil to see the effect of his mistakes. In turns, loops or half-rolls he has time to allow the pupil to correct his own errors, but when teaching landing he must frequently interfere in order to save the undercarriage from destruction.

When the pupil has learned to land reasonably well he is shown how to manage his engine, on the ground and in the air, and an hour or two is then spent with him in complete control, the instructor being there merely to prevent accident. After that it only remains to teach sideslips and cross-wind landings and take-offs and to let the pupil execute a few landings in fields near the aerodrome. At this stage he is generally able to assimilate his instruction very quickly, and as a rule not more than an hour is spent on these last subjects.

So, after anything from seven to twenty hours' dual or more, the pupil is at last sent up alone. The "first solo" is not nowadays the nerve-racking ordeal for all concerned that it was in 1915. The novice has been convinced in his own mind during the last two or three hours of instruction that he is quite capable of flying by himself, and always chafes considerably at any delay in sending him up alone. He almost always takes off well and lands passably; sometimes he spins and loops on his first flight. All that remains to be done is to give him a few minutes' dual each day as a "refresher," to watch him carefully for the development of faults in style and to correct them immediately by further dual control.

Further instruction is usually necessary in forced landings, and every means should be taken to improve the pupil's judgment before he is allowed to fly across difficult country. Two out of three accidents to newly trained pilots are caused nowadays by forced landings due either to engine failure or to loss of direction.

Much more time is, of course, spent on the dual control instruction of each pupil than was possible during the war, but the extra expense involved is very much more than balanced by the comparative rarity of "crashes." The average pupil in 1915 probably had about five hours' dual as against ten or twelve given to-day, but he probably damaged aeroplanes (to say nothing of himself) to the extent of several hundred pounds before he became proficient.

Accidents do still occur, as they will so long as man is human, but they are comparatively rare; as a rough guess one would have expected the 1915 pupil to break at least two aeroplanes completely, besides smashing half a dozen undercarriages; at the present time the average seems to be about eleven pupils trained for one aeroplane and four undercarriages wrecked.

On the chance that they may prove interesting I will give a few figures relating to two batches of pupils recently trained in the unit in which I am now serving.

The first batch had done no previous flying when their training began. The

average time spent in dual control with each pupil, up to the time of his first solo flight, was 15h. 35m. The shortest time required by any pupil was 10h. 35m., and the longest 32h. 10m. This last figure is quite exceptional, over 20 hours being spent in landings. The pupil was discovered to be suffering from eye trouble, and after a course at a specialist's became an excellent pilot.

All the pupils in the second batch had flown as passengers for about eight to ten hours before their training as pilots began. In their case the shortest time required for dual was 6h. 10m., the longest 16h. 25m., and the average 10h. 40m. The same instructors taught both batches, and the saving, with the second, of nearly five hours' dual per pupil can therefore only be attributed to "air experience" gained while flying as observers.

A great deal of trouble is taken in my unit to make the pupils conversant with the simple theory of flying before they begin their instruction. The uses of each control in all positions of flight, the effects of engine torque and slip-stream, the theory of landing and taking off properly are all carefully explained. The pupils listen most attentively and always remember what they are told until the moment arrives for them to go into the air. Then of course everything is forgotten, and not one pupil in a dozen believes that he has profited by what he has been told. Most of them think the reverse, and feel that they have been muddled and confused. As soon as the first excitement has subsided, however, the "theory" which has been taught them begins to assert itself and progress is much quicker. The instructor is also able to curtail his "patter" considerably, since the pupil knows most of it by heart before he goes into the air.

I will conclude with a few general observations upon instructors, pupils and aeroplanes.

The instructor must of course be a good and accurate pilot, but mere ability to fly well is far from being the most important of the necessary qualifications. He must love flying for its own sake; he must be patient, sympathetic and tactful; he must be able to analyse clearly his own movements in flying and those of his pupils; above all he must possess the power of imparting to them his own enthusiasm for flying.

The difficulties which instructors encounter in the temperaments of their pupils are many and various. The marked success of a particular teacher with all types of pupil is often attributable to his tact rather than to his knowledge or his energy. Some pupils are keen but clumsy, others have good "hands" but no "head"; one will be lazy and indifferent, another so highly strung and sensitive that a reproof snapped at him into the telephone will make him incapable of learning anything during the whole of the remainder of the lesson.

It is only by having his temper in perfect control and by the development of tact and a knowledge of human nature that even the best pilot can become a first-class instructor.

The first requisite in a pupil is the desire to learn to fly. He must also have a certain amount of mechanical common sense, good eyesight and perfect co-operation between brain and muscle. He probably requires a good many other qualities with long medical names, connected chiefly with the sense of balance and the power to judge angles and the rate of approach of the ground in landing. The pupils who learn most quickly and become the best pilots are generally those who are good at outdoor games and sports and keep themselves fit. The first two pupils to fly solo in the second batch referred to above were the only two who rode regularly to hounds. (The third, incidentally, was said to possess considerable knowledge of the turf!) Though good horsemen usually have good hands when flying, there is of course no reason why they should have good judgment or good eyesight. Almost anyone who leads a healthy life and has normally developed senses can be very easily taught if his heart is in the business.

The requirements in the aeroplane are that it should be reliable, simple and of suitable design. The cowl and front of the fuselage should be straight, and horizontal when the aeroplane is in flying position. It should have a high factor of safety, both mechanically and (if this is the right word) aerodynamically. The stalling speed should be low, and the feel of the controls should give early and ample warning of its approach; the smaller the space required to recover from a stall or spin, the better. The undercarriage must be strong and easily replaceable in case of breakage. Above all, the aeroplane must be sensitive in flight, and its controls must be well suited to one another. For example, heavy aileron and sensitive elevator controls do not go well together.

The Avro fulfils all these requirements and has the double merit of being very easy to fly, but not at all easy to fly well. Small errors are very well shown up without any risk of the pupil's suddenly losing control.

I am very well aware of the shortcomings of this paper, especially its incompleteness. The training of pupils on more advanced aeroplanes and the art of turning a pilot into an instructor are both outside the scope of my present duties.

I have confined myself to those aspects of the subject with which I am acquainted, and to description rather than history or speculation.

If I have laboured the obvious I can only say that I expected to have to do so; if I have omitted most of the points of interest, as I probably have in fact done, then there is every hope that we may at least hear a profitable and lively discussion.

DISCUSSION.

The CHAIRMAN, in opening the discussion, said he had a good many pangs of conscience, because he was the person responsible between 1914 and 1915, when the author had said there was no system and that the instructors did not know how to teach. He did not believe that when the war broke out there were in this country twelve men who knew how to teach; he doubted whether we had six. Those we had all taught on different systems. We really knew nothing about flying then, and had to encourage everybody to go on their own lines in order to learn what were the best methods. On top of that, when the Royal Flying Corps mobilised, they took every fit man to the front, and those left behind were either unfit for service at the front or were not considered sufficiently good pilots, and they had *force majeure* to be turned into instructors on the spot. He was always opposed to preliminary training, *i.e.*, training on an old Maurice Farman or box kite before a pupil was allowed to go to a fast machine. Curiously enough, he believed that every instructor in 1914 and early 1915 was dead against him. He insisted upon making experiments on Avros and B.E.2s, and in both cases the experiment failed because the instructors were not good enough. Then came what the lecturer called the "instructional revolution"—and he had omitted to mention the leader of that revolution, Smith-Barry, who was a wonderful pilot. He came spinning out of the clouds like an angel from heaven, so far as he (the Chairman) was concerned, and as the author had said, "in an incredibly short time the leaven from the first instructors' school had permeated the whole service, leading to a vast improvement in flying ability and moral." The service owed a great deal to Smith-Barry for what he had done. He was open to correction, but he believed that it was not until 1916 that a pilot—he believed he was French—discovered the proper and perfectly simple method of getting out of a spin, and until that was discovered it was impossible to do what Smith-Barry had done. He had learned it from the French pilot, and had put it into practice himself, and from that time we were miles ahead of the French or anybody else. Park's dive, he believed, was a case of spinning and happened in 1912. Somehow Park had got out of it, he did not think he knew how, and there had been a tremendous discussion on it, but he believed that Mr. C. G. Grey published the first

correct theory in "The Aeroplane," *i.e.*, one only had to push the rudder straight and put the nose down and the machine would come into control again. Speaking again with regard to training in the early days, the Chairman said that before the war they tried to give pilots at least 30 hours in the air before they were given wings, but they were often driven to give them less. He himself had qualified for his wings in 13 hours. In 1915 he believed that they pushed some pilots over to France after only 12 hours in the air. He had often wondered how things would have worked out if they had delayed matters by giving everyone twice as much training as was actually received; he was certain we should have had far fewer casualties. One of the qualities necessary in an instructor was certainly patience. Quite a number of our finest pilots had started so badly that they had nearly been "turned down" during the early stages of their training. He believed he was right in saying that Ball was one of these. He was nearly turned down at the Central Flying School, but he was so keen that he was given another chance, and he turned out to be one of the finest fighting pilots the world had ever seen. It was hard to imagine a better system of training the military pilot than that at present adopted. The Avro was a perfect machine, the engine was good enough for the purpose, and with them it was possible to get into any position in the air with perfect safety. As to commercial flying, if aerial transport were to boom in two years or so, we should not have sufficient trained pilots, and the problem would arise as to how these pilots were to be created. Their training would be different from that of a military pilot. The latter had to do every form of stunt, had to do without instruments, etc. The commercial pilot did not want the particular qualities demanded from a fighting pilot. Colonel Searle, when he was managing director of A.T. and T., had evolved an interesting theory. He had suggested dual control on every machine, and that an apprentice pilot with no training except as a mechanic should be put up beside the pilot and fly with him for six months or a year. This apprentice would act as mechanic to the pilot, and the pilot during his flights would slowly get him into the way of working the controls. He was not at all sure that this was not a possible method. The commercial pilot need never stunt but would have to fly in cloud, in the dark and every sort of weather and could always use his instruments. It might be urged that that sort of training might not make a good service pilot. Well, it would not make a good fighting pilot, but he would be useful for night flying, bombing, etc. He agreed with the lecturer that flying was perfectly safe. The weak point of flying was that one could not afford to make a mistake. Eliminate mistakes and flying was the safest thing in the world.

Wing Commander BOWEN recalled his early training and his training after the war and paid a tribute to the work of Smith-Barry. He was chiefly interested in the human reactions which came into play in flying, and his own knowledge on this subject was taken almost entirely from Dr. V. Anderson's extraordinarily interesting book on "Medical and Surgical Aspects of Aviation." There were three senses used in flying, and if one analysed the present system of teaching people to fly one realised that practically only one sense was really trained, *i.e.*, the visual sense. Although the author had mentioned that pupils were taught to listen to the note in the flying wires, he rather gathered that that was the sole extent to which the auditory reaction was trained at all. The third important reaction was the tactile reaction, or sense of touch, and that came in to an extraordinary extent in stunting. It should be explained to cadets exactly how these reactions worked, and how extraordinarily important it was to keep themselves fit. The visual reaction was roughly 1/5th of a second, and the others were both about 14/100ths of a second in a normal person. If they were not kept fit they might go down to half a second. He had tried flying with his eyes shut, at a safe height, and had found it extremely easy. The more one left everything entirely to one's sub-conscious self, and trusted to tactile and auditory reactions, the simpler it was. People had to fly in clouds, and he suggested quite seriously

that they should be taught to fly to a certain extent with their eyes shut, and come to trust to their natural reactions. Continuing, Wing Commander Bowen referred to the turn indicator which was being developed and might be of interest to flying instructors, particularly to those training pilots for civil aviation. It was getting to a point now at which it was beyond the experimental stage, and it was solely a question of getting the thing to stand up to ordinary service. It would be interesting to know whether it was considered by expert flying instructors that it would be of any utility in their work. With regard to civilian pilots, it seemed to him that one of the greatest troubles in the past, and to a certain extent now, was in trying to impress upon pilots the fact that if they had instruments to help them they should get 100 per cent. out of their instruments. For flying big, heavy machines we were bound to come more and more to instruments, and he suggested that when training pilots the full importance of instruments should be impressed upon them.

Mr. A. V. Roe said serious consideration should be given to the question of starting from the ground, that is, he thought the landings should be taught first, not last, the pupil to be taken for "hops" or short flights near the ground for a start, allowing the pupil more or less to handle the machine, the flights to be gradually increased in length and turns indulged in until the pupil was thoroughly used to landing, then the usual existing course could be taken. He thought after a preliminary course of this nature the total flying hours required in order to learn to fly would be reduced. He drew attention to the fact that the world's record for quickly learning to fly was made by Pemberton Billing, who obtained his certificate in about an hour before breakfast one morning, without any previous flying experience. Some object to this method, for they say the pupil would be rather apt to seize the control stick, which would be dangerous near the ground, but it was a simple matter to fix springs on the controls, so that the instructor could master the pupil. He noticed in the paper that one man had taken 20 hours to learn to land, but if one started from the ground then one got some idea of how far the ground should be from the seat when landing, and it seemed much easier to land the machine if a number of preliminary hops had been made. As to controlling the aeroplane, the position of the pupil behind the instructor was very good. He personally liked that idea because he thought it gave the pupil more confidence, whilst the instructor could not so easily see the nervousness of the pupil if he was inclined that way (laughter). Then there was the question of the communication between the instructor and pupil. Indicators could be used, but a good telephone wanted a lot of beating, especially as now there are telephones in which the voice is amplified. Referring to economy, Mr. Roe said his firm had been experimenting with an air-cooled engine, which was considerably more economical than the rotary type, and of course had advantages over the water-cooled engine.

Group Captain E. F. Briggs said the scheme in progress at present for the development of flying instruction was very much better than the old scheme, and the short time taken for the average pupil to become really proficient vindicated its adoption. In the old days at Eastchurch they never had much instruction, although he did not think a great number of undercarriages or machines were broken up. One instructional aeroplane had lasted for something like $2\frac{1}{4}$ years. He had been an advocate of using instruments for starting the instruction of pupils. In the olden days one had to rely entirely on feel, and he had had the advantage of being in close touch with the designers of the first air speed indicator of the type now in use, when first brought out, and of the application of Wright's principle of the "piece of string," with which one could accomplish in some measure what the gyro turn indicator now allowed one to do in clouds. Again, on the question of levels, he believed that the first one used was an old Admiralty boiler gauge glass, slightly curved, with a cork at each end. Personally, he preferred the piece of string to the cross level. Pilots should be instructed in the

use of such instruments as are fitted in aircraft. He was rather sorry they had heard nothing about seaplane instruction. He did not quite know what was the best method to adopt in this connection. Some people maintained that they ought to have small flying boats for training, and others the two-float type. He understood that at present most pupils who went in for sea work first qualified on land planes, then on the two-float types, then on the big boats with dual control. Dual control as in the big boats would probably be the best method for instructing commercial pilots in large land machines, although he would rather like to venture an opinion which was that all pilots, whether for naval, military or civil flying, should go through a common initial training, and those who went in for commercial work should transfer to the reserve. By this system prospective commercial pilots would have had full initial training and would obtain their final instruction on dual control with the big air-line pilots in the heavy machines. He however imagined the insurance people might create a stir if an accident occurred, and if they knew that one of the pilots under instruction was in command at the time and possibly doing his first landing with twelve passengers and valuable goods on board. With regard to the relative positions of the pupil and the instructor, a two-float dual control seaplane was just being completed, but in this type of aircraft one had far more controls to manipulate than in the "Avro," as there was the "flap gear," tail adjusting gear, radiator shutters, etc., and other adjustments to make. In this particular seaplane the pupil is situated in the seat he would normally occupy were he flying by himself, and he asked the author's opinion, from an instructional point of view, as to whether this position should be occupied by the pupil or the instructor. As to air-cooled engines, unfortunately, the Air Ministry had such a stock of "Mono Gnomes" that there was very little likelihood of getting air-cooled engines adopted for training for some time, although he believed that the amount of money saved in the long run would more than outweigh the cost of introducing air-cooled engines into the training service. In the East, particularly, air-cooled engines would be economical, because he believed the sand played havoc with the mono Gnome. The engines in the East did roughly 20 to 30 hours running, and a good radial air-cooled engine might perhaps run 150 or 200 hours without overhaul.

The CHAIRMAN asked whether that would be a fixed engine.

Group Captain BRIGGS said yes. Continuing, he said it seemed a pity that pupils had to be instructed on the effects of the gyroscopic action of the rotary engine. He presumed that these rotaries would be replaced before long by high power fixed radial engines. When this transpired it would appear advisable to put the pupil through his initial training on an engine, or a type of engine, which would be in use in other service aircraft. With regard to Mr. Pemberton Billing learning in one hour, it happened that there was a pretty considerable bet at stake and this probably accounted for the short time taken to obtain the "ticket."

Captain W. H. SAYERS said he first went up in 1911 as a passenger with a well-known pilot, on his first flight after he had taken his ticket, and had had an excellent opportunity of watching him learn to fly (laughter). Fortunately, he learned very quickly. He had another experience, when he had to run the Avro Flying School at Brooklands. Not being a qualified pilot, he was theoretically not allowed to fly. When a pupil stopped his engine at the end of the ground he had adopted the practice of getting into the seat, getting the pilot to start his engine, and then himself taxi-ing the machine back. This was an excellent deterrent to this annoying habit. He had found, however, that it was much simpler and much less dangerous to fly it back at a height of somewhere about 4ft. off the ground, with the engine throttled well down, until one day, when crossing the corner of a sewage farm, something hit the machine and he found himself over the sewage farm. He was forced to climb, make a very shaky turn round the sheds and land. The latter required five attempts before success was

attained and the effect on his and the pupil's nerves put an end to flying for that day.

Since then he had been subjected to instruction of the dual control type in various degrees of completeness, and his last experience had been at the hands of a "Gosport" type instructor. This was not so much instruction as a demonstration of the things an Avro ought not to do, but did do, and so was perhaps not a fair sample.

But it was the most terrifying experience he had yet had in the air—much worse than his first circuit. He had been learning to fly for the last ten years, but officially did not know how to yet. The old method of teaching a pupil on a relatively low-power machine, which could not get very far off the ground, and turning him loose, was capable of producing extremely good results, with a good machine and a good, sensible pupil. In 1912 they had turned out something like six pupils on one machine, and without breaking anything more serious than one wire.

The pupil of to-day knew more about flying before going into the air than anyone knew in the old days.

The Chairman had referred to Park's dive and said Park did not know what happened. He (Captain Sayers) was associated with him at the time it happened and he did know very definitely what he did.

The CHAIRMAN: It was a spin?

Captain SAYERS replied that it was, but Park knew definitely that he got out of it by putting his stick forward and centralising the rudder. With regard to civil pilots, everybody would agree that they ought not to stunt. At the same time, it was undoubtedly the fact that they ought to know how to stunt, and ought to know that they knew. There was always the possibility of getting into an awkward position from which one could only recover by something in the nature of a stunt.

Dr. A. P. THURSTON said it was a well accepted fact among psychological specialists that most men might be divided into two main types, *i.e.*, visualists and auditives. The latter type did things more or less by happy inspiration, without really knowing how and relied instinctively on the sub-conscious brain, whereas the visualist belonged to the hard thinking scientific type, who must be convinced definitely as to every step in the process before allowing the sub-conscious brain to take control. The northern races had a much larger proportion of the visualist class, and the southern races a larger proportion of the auditive, but whether a man belonged to one class or the other, the sub-conscious brain composed the great mass of the brain and was much more ancient and more highly developed than the conscious brain. It seemed to him, therefore, to be an excellent thing to instruct a pupil most carefully what to do when various difficulties arose and why those difficulties arose, and then to take him into the air and show him how to get out of those difficulties. It used to be the practice during the war to take a pupil into the air, put the machine into a spin during his first flight, tell the pupil through a telephone that he was in a spin and that it was quite easy to get out. What he had to do was to centralise the rudder and push the joy-stick forward. Then he was told he would be put into a spin again and would have to get out himself. That gave him confidence which he never forgot. Engine failure had not been brought into prominence that evening and was in the speaker's opinion the second great danger. Engines failed just at the psychological moment, when they should not, and they could fail in the air in only three ways—spark, pressure or throttle, except, of course, for mechanical breakage. If the instructor caused the engine to fail unexpectedly in the air in various ways and the pupil had it thoroughly ingrained in him that he should switch off and switch on to test the spark, then try the pressure and finally the throttle, it would pull him out of a nasty corner many a time. Before that wonderful invention

of Mr. Mayer engine failure due to loss of air pressure was very common, and if the engine stopped, after first testing the switch, he would turn automatically at once to the air pressure to see that sufficient pressure was recovered to supply the petrol. Another point which should be impressed upon a pupil, until it became automatic, was that when coming down the pressure of the air increased but the pressure of the air in the tank did not. It was therefore necessary to keep pumping or else he would not have the engine when he wanted it. The drilling in of these little things seemed to give confidence which could not be obtained in any other way. The development of finesse in flying could more or less be left to the pupil himself. As to landing, he had always found it extraordinarily difficult to make a full three-point landing, whereas if they were allowed to come down a little faster, and not make altogether a good three-point landing, they would make a much more certain and much more competent landing. Our machines should be designed so that it would be possible to make a good three-point landing without having to pull up the nose of the machine 10 to 15 degrees, and so obstruct the view of the ground and set the pilot's judgment out by altering the inclination of all the lines of the machine relatively to the ground. That was one point in regard to which the science of construction could be considerably improved at the present moment. Pilots could then land practically at the same inclination as that in which the eye had been trained when flying at height.

He was glad Captain Sayers had pointed out that the honour of discovering how to get out of a spin is due to Lieutenant Park, R.N. He remembered the incident quite well on Salisbury Plain in 1912 and found the information of use long afterwards when he got into an involuntary spin.

Flight-Lieutenant BALFOUR said he believed the author was wrong in regard to the method of instruction which taught the pupil to fly level, then turn at an angle of about 45 degrees first and then vertically afterwards. The best method was to teach, first, to fly level, then vertical, and then come back to the 45 degrees. Flying at 45 degrees was far harder than flying vertically owing to the elevator fulfilling a dual function when machine is at 45 degrees. With regard to moral, the whole thing was one of the instructor possessing moral which he could impart to his pupil. Referring to Mr. Roe's point as to training a pupil from the ground. This would give a pupil too much to think of at one lesson. By teaching in the air first, it would be found that it was as much as a pupil could do to learn to control a machine in the air in three or four hours. Do not mix him up by teaching of flying level and landing in the same lesson; they should be kept as separate and distinct.

Flight-Lieutenant FORBES-BENTLEY said that in the old days, 1912 and 1913, one always knew where there was an aerodrome, because there were generally lorries or carts going towards them carrying broken machines. During the war he was very close to an aerodrome where a number of pupils were being taught on Henry Farmans, and there also there were numerous crashes. He backed up Captain Sayers in saying that Lieutenant Park did know how he got out of his famous dive. Speaking of the instruction at Cranwell, he had had the rather unique experience of having been attached there for fourteen months, in a part of the aerodrome from which he had a good view all round, and during the whole of that period he had not seen a crashed machine, which compared very favourably with past records, and showed the value of the training advocated by the lecturer.

Squadron-Leader PORTAL, replying to the discussion, first dealt with the Chairman's remark that the method of coming out of a spin was discovered by a French pilot in 1916. When he (the speaker) was an observer, about the middle of 1915, his pilot got into a perfectly good spin in a Morane, about 300ft. from the ground, and they had got out of it before reaching the ground. He agreed with Wing-Commander Bowen as to the importance of the three senses used in flying, and that the tactile and auditory senses were very, very important, but

maintained that to teach a pilot by means of those two would be practically impossible. They must teach a pilot by visual methods and he would soon, from his own experience, get the help which all pilots derived from tactile and auditory senses. As to the use of turn indicators, he was inclined—as the duties at his station were only concerned with what might be called the simple, straightforward A B C of flying on the Avro, which formed the basis of other sorts of flying—to the view that their introduction would lead to complications in elementary instruction. Both Mr. Roe and Captain Sayers had advocated training from the ground. There were, however, two very serious objections to that method, in practice. In the first place, there might be 18, 20 or 25 pupils learning at the same time, and if they had 25 pupils rushing about on the ground at all angles and speeds, and probably with their heads inside the cockpit wondering what was happening to the throttle, there would be more crashes than occurred in a modern ballroom, with far more serious results. An even more serious objection was that in any wind that method could not be pursued. A pupil could run along into the wind all right, but if there were a wind of about 20 miles an hour, he would stand a good chance of being blown head over heels when he turned to come back. That would be all the more likely when there were a lot of pupils turning quickly, and trying to avoid running into each other. In the air, however, one could teach in a 50-miles-an-hour wind just as well as in a dead calm. Group Captain Briggs had referred to instruments. He (the speaker) very strongly maintained that it was folly to teach a man from the start to depend in any sense on his instruments. Probably he did not lay sufficient emphasis on it in the paper, but he was serious about the earwig. If an earwig did happen to get into the pitot tube, and woke up, it might mean that a pilot would be killed if he was depending on his instruments. That was an extreme case, but that was the principle in the minds of instructors. No instructor ever thought of mentioning the word "instrument" to a pupil in these days. They had their value, but it was not in teaching elementary flying. He was in agreement with Group Captain Briggs that the pupil should be in the same seat throughout instruction as that from which he would fly an aeroplane afterwards. Dealing with Mr. Thurston's remarks, the author said he would rather fly with a visualist than an auditor. Although he recognised the great ability of Flight-Lieutenant Balfour, both in the air and elsewhere, he did not agree that the vertical turn should be taught first. Flight-Lieutenant Balfour was in a minority of one, with an opposition of about 15 or 20 instructors who were very nearly as good as himself, and the speaker took it on their authority and practical experience that the proper place for the 45 degrees turn was immediately after the level flying, the reason being that it was not such an unexpected position to get into as the 90 degrees turn. That was the real reason it was taught after level flying. As to Flight-Lieutenant Balfour's remarks on moral, he (the author) did not lay sufficient emphasis upon it in what he had said in the paper. He realised that what Smith-Barry did for flying was even more from the point of view of moral than from pure technical efficiency.

The CHAIRMAN said he was glad to discover that we British could claim to have found out how to come out of a spin. He never knew it before, and it was a pity that the simple cure for the spin had not been generally made known earlier. The spin was one of his worries in 1914 and 1915; none of our instructors were prepared to go into a spin and try these methods of coming out at that time. Although he agreed with the lecturer that it was sound to train pilots without instruments, he did not agree with Wing-Commander Briggs that it was possible to fly in cloud without instruments with safety. In bad clouds even the best of pilots had been thrown out of control. The younger de Havilland was nearly killed when flying in really bumpy storm clouds over mountains. The turn indicator was the most valuable instrument we had at the present time. We had outlived the idea of training "from the ground" as Mr. Roe termed it. He was convinced that the dual control method was much the best way of teaching normal

men to fly, both from the economical and safety points of view. He had thrown down a bone of contention in the shape of Colonel Searle's idea and several people had risen to criticise it. At heart he personally was convinced that all pupils had to become *airmen* first, and the best way to teach them was a thorough training on an Avro machine, followed by training on specialised types. The trouble he saw in front of us was that if aerial transport really began to move we should not be able to get a sufficient number of properly trained pilots, and we might have to find a means of producing them quickly without the advantage of the Avro training, which, of course, was too expensive for an air transport firm to adopt. In conclusion, the Chairman expressed the thanks of the meeting to the lecturer for his most interesting paper.

The thanks of the meeting were accorded with acclamation and the proceedings terminated.

REVIEW.

Research in Industry. By A. P. M. Fleming and J. G. Pearce. (Sir Isaac Pitman and Son.) Price 10s. 6d.

With the many ills brought by the war there were a few gains; one was the increasing recognition of the importance of scientific research in the national life. Readers of Professor McDougall's well-known book, "National Welfare and National Decay," will recollect the attention which that psychologist gives to the idea that nations survive only in virtue of their power to produce leaders whose mental outlook shall be fully equal to the growing complexity of the problems which changing life presents. Much of that complexity is directly due to man's gradual conquest of the forces of nature; much to the greater consciousness of the conditions of their lives due to the spread of education among all classes. The idea is a compelling one and, if accepted, renders it of first importance to facilitate in every way the path of the research worker in the hope that, by this means among others, our race will always be "on the top" of our industrial problems as the latter arise.

The present book is therefore doubly welcome. It discusses the nature of research, the best material means for its efficient performance, the nature of the research worker in person and the international character of research. Present-day governments in the leading world states are more or less alive to the situation; possible alternative governments in such states are a more uncertain factor. But it will be noted with pleasure by many readers that the authors are able to place on record a manifesto by the American Federation of Labour in favour of research which opens with the very striking recognition that "whereas scientific research and the technical application of the results of research form a fundamental basis upon which the development of our industries, manufacturing, agriculture, mining, and others must rest; and whereas the increasing productivity of industry resulting from scientific research is a most potent factor in the ever-increasing struggle of the workers to raise their standard of living, and the importance of this factor must steadily increase since there is a limit beyond which the average standard of living of the whole population cannot progress by the usual methods of readjustment, which limit can be raised only by research and the utilisation of the results of research in industry. . . ." The breadth of view here expressed by those who would not be expected by their education to be so much in advance of the ideas prevalent but a few decades ago is most welcome. A wide realisation of its wisdom will be of immense benefit.

The authors correct not a few misapprehensions in their analysis of the nature of research. It frequently happens that attempts are made to lay out plans for research work—whether "pioneer" or "applied," according to the authors' division—to a definite programme and to prescribe at once anything of the nature of the dreaded "overlapping" of research. The authors point out, on pages 47 and 134, that research work in pure science cannot be systematised, that each worker should be allowed to proceed according to his vision, that there must be freedom of action for the worker to select his subject and develop it, and further that overlapping, "far from being a crime," is often a necessity. The authors rightly stress the immense importance of facilities being afforded for the publication of results; they point out that the extra emoluments obtained in industrial research, as compared, for instance, with University fellowships or lectureships, will not compensate the worker with the true research spirit if publication is denied him.

A very interesting feature of the book is the series of illustrations of research laboratories in every part of the world; they are seen to be ingeniously and ably

planned in their internal arrangements. But they are usually, alas! found to be designed externally with but little regard to the elements of beauty. Surely the time must be near when it will be realised that the beauty which always accompanies a design aptly fitted to its purpose may fittingly (indeed profitably) be associated with beauty of external environment.

That the authors have first hand knowledge of the subject on which they write could easily be established on internal evidence alone. What research worker will not recognise the truth of the advice that: "It is a good plan to arrange a certain amount of work as a relief to the research work, and this may even be routine work. The performance of a set task at specified intervals well within a worker's capacity will restore self-esteem which is apt to dwindle if a long period of non-success or failure of inspiration occurs in performing a major research."

We are grateful to the authors for their labours and we hope that those responsible for research work in aeronautics will take an early opportunity to study this book.